Examining the Role of Motivation and Mindset in the Performance of College Students Majoring in STEM Fields

by

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To my grandchildren, the future scholars, Daniel, David Omead, and Fatemeh Saba

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ABSTRACT

In order for the U.S. to continue its superiority and competitiveness in science and technology worldwide, it will need to produce one million more graduates in science, technology, engineering, and mathematics (STEM) subjects than it is currently expected over the next decade. One of the national priorities of the U.S. education system, therefore, has been to supply a sufficient number of graduates in the STEM fields. Of the main obstacles that prevent college students from majoring in the STEM fields are the students' mindset and lack of motivation. The purpose of this mixed-methods study was to examine the influence of motivation and mindset interventions on students majoring in STEM fields in order to enhance and improve the students' success in their pre-calculus course.

The study included both quantitative and qualitative research questions. To answer the quantitative research questions, three instruments (i.e., PCA, SMQ-II, and the Mindset Survey) were used. The analysis of the PCA and SMQ-II scores, using ANCOVA for controlling the pre-existing differences in pre-test scores, indicated no statistically significant difference between the two groups in terms of pre-calculus achievement and motivation toward learning mathematics. When comparing the two groups at post-test with regard to mindset, there was a difference in the proportion of participants with a growth mindset toward intelligence (3%) and mathematical ability (10%), where the experimental group had the higher proportions. In addition, there was an increase in the proportion of participants in the experimental group with a growth mindset toward intelligence (27%) and mathematical ability (4%) from pre- to post-interventions.

Qualitative data such as interviews, written reflections, and classroom observations were used to answer the qualitative research question. Although all case study participants perceived benefits from the motivation interventions, they did not report a change in their motivation toward learning mathematics. All case study participants, whether they started out with a growth or a fixed mindset, perceived themselves to have a growth mindset toward intelligence and mathematical ability after the interventions However, it was not clear whether the interventions were effective enough for the students to maintain the growth mindset beyond the semester of study.

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CHAPTER ONE: INTRODUCTION

Introduction

Science, technology, engineering, and mathematics (STEM) play a vital role in our everyday life and exert a significant impact on the economy and growth of the society (Moursund, 2011). Where novelty, invention, and quick adaption are necessary components for successfully competing in the worldwide economy, the lack of talented STEM laborers in the workforce will result in declining prosperity (Thomasian, 2011). Growing doubts about the capability of the U.S. to measure up in the international market have directed efforts to increase the quality and the quantity of students who are majoring in STEM fields (e.g., National Governors Association, 2007; National Research Council, 2012; National Science Board, 2007). To address this problem, the STEM Education Coalition was formed in 2006 to "raise awareness in Congress, the Administration, and other organizations about the critical role that STEM education plays in enabling the U.S. to remain the economic and technological leader of the global marketplace" (STEM Education Coalition Objectives, n.d., para.1). Six years after the formation of this coalition, the President's Council of Advisors on Science and Technology (PCAST, 2012) stated in a policy report that in order for the U.S. to maintain its supremacy and competitiveness in science and technology worldwide, over the next decade it will need to produce one million more STEM specialists than it is currently anticipated to produce. Despite the importance of this goal and its vital role in the U.S. economy, educators at the postsecondary level cite a variety of data and trends that hinder reaching this target (e.g., Beede et al., 2011; Chen & Soldner, 2013; Gonzalez & Kuenzi, 2012; Heilbronner, 2011;

Hossain & Robinson, 2012; Peterson, Woessmann, Hanushek & Lastra-Anadón, 2011; Silva & White, 2013).

Obstacles

There have been many areas identified as obstacles for improving the quality and quantity of STEM graduates from college and universities. These factors include: teacher qualification; worldwide ranking; low participation of females, African Americans, and Hispanics; and two non-cognitive factors, lack of motivation and students' mindset. Each of these will be described in the following sections.

Teacher Qualification

Many observers have identified one of the major sources for shortcomings in student mathematics and science achievement as the nation's teaching force (Ganzalez & Kuenzi, 2012). The American Council on Education (ACE, 1999) reported that when teachers complete more mathematics courses, then their students in turn learn more mathematics. There have been numerous studies and essays, however, about the other types of knowledge essential for teaching mathematics in elementary and secondary schools in the last 30 years (e.g., Ball, 1996; Cochran, DeRuiter & King, 1993; Grossman, 1990; Ma, 1999; Shulman, 1987; Wilson, Shulman, & Richert, 1987).

The National Council of Teachers of Mathematics (NCTM, 2000) stated that producing teachers who merely own a greater knowledge of mathematics does not guarantee that it will empower their students to acquire mathematical ability and deep conceptual understanding. Similarly, many researchers like Dewey, have declared that the knowledge of presenting a subject is different from the knowledge of teaching (e.g., Ball, 1990; Mewborn, 2001; Shulman, 1986). These researchers claim that student success is not only influenced by subject matter knowledge of teachers but also by their pedagogical content knowledge. Here, pedagogical content knowledge is defined as that knowledge which enables the teacher to understand the subject matter, to discover different ways to represent it, and to create and evaluate analogies, metaphors, and specific examples of subject matter concepts when performing the tasks of teaching (Ball, 1990; Hill, Rowan, & Ball, 2005; Shulman, 1986). Shulman (1986) emphasized combining the two knowledge fields (i.e., subject matter knowledge and pedagogical content knowledge) in teacher education programs.

Unfortunately, many U.S. mathematics and science teachers who are currently teaching in high schools lack this fundamental subject matter knowledge since they are teaching subjects in which they have not earned a baccalaureate degree (Ganzalez & Kuenzi, 2012). An estimated 17% of high school teachers in 2007 did not major in the subject they taught, whereas 28% of mathematics teachers did not major in mathematics. Additionally, mathematics teachers who majored in mathematics were less likely to be subject-certified than other teachers who majored in what they taught (Ganzalez & Kuenzi, 2012). Mathematics education at the elementary level is not promising either. Elementary teachers' preparedness in mathematics is at an even greater disadvantage when compared to high school teachers because 46% of elementary teachers have not taken courses in either advanced mathematics or how to teach mathematics (Banilower et al., 2013). However, despite the lack of teachers' readiness in teaching mathematics, teachers are the fundamental factor in our education system (Shulman, 1983). Therefore, one of the major obstacles in obtaining more high school students interested in majoring in STEM is the lack of knowledgeable teachers who are capable of combining subject matter knowledge with pedagogical strategies to create appealing learning environments in teaching all kinds of learners (Ball & Bass, 2000).

Worldwide Ranking

According to PCAST (2010), the performance of American students on science and mathematics tests is consistently below the international average. The Organization for Economic Co-operation and Development (OECD) reported that among 34 countries, American students performed below average in mathematics in 2012. Similarly, results from the Program for International Student Assessment (PISA) indicated that the ranking of the mathematics performance of 15-year-old American students declined from 25th in 2009 to 27th in 2012. This poor performance of American students in mathematics may have contributed to another problem: the slow growth of the number of graduates from colleges and universities in STEM fields compared to other nations.

In the past decade, the U.S. has fallen behind other countries in producing graduates with STEM degrees. According to Chen and Soldner (2013), the ratio of STEM to non-STEM students who graduated with a bachelor's degree in U.S. is the lowest in the world. For example, from all of the bachelor degrees awarded in U.S., only one-third are STEM majors; alternatively, STEM students in Japan, Singapore, and China make up more than half of the degrees awarded in those countries (Thomasian, 2011). Moreover, the percentage of doctoral degrees earned by international students in the U.S. has been steadily increasing since the mid-1970s. According to the National Science Foundation (NSF), international students earn approximately one-third of all science and engineering doctoral degrees in the U.S. They have also earned half or more of U.S. doctoral degrees in computer sciences, economics, physics, and specific fields of engineering (Gonzalez &

Kuenzi, 2012). China awarded the highest number of doctoral degrees in natural sciences and engineering, outnumbering the U.S. in 2007 (National Science Foundation, 2014). Similarly, China has attained the highest mathematics score in worldwide rankings reported by PISA assessments (2012) during years 2000-2012 except for the year 2006, in which Finland scored two points higher than China, achieving the highest mathematics score among 57 countries. Therefore, perhaps the poor mathematics rankings of U.S. students globally indicate an inability of educators to produce more college students majoring in STEM fields in college since mathematics is a foundation for all STEM disciplines (Shaw & Barbuti, 2010).

Lack of Participation

Although the demand to increase the number of students who graduate in STEM fields is at an all-time high, educators in colleges and universities are faced with a demographic challenge (National Academies Press, 2011). The lack of participation of females, African Americans, and Hispanics is apparent in STEM fields despite their growing presence in colleges (Aud et al., 2013). Each of these underrepresented groups will be described in the following sections.

Females. In the early 1990s, U.S. females were about as likely as men to earn a bachelor’s degree or attend graduate school. By the middle of the decade, however, women began to top men in college attainment and showed higher rates of graduation (Bidwell, 2014). Furthermore, more than half of U.S. college students are now female and over half of all bachelor’s, master’s, and doctoral degrees in the U.S. are granted to women (Gonzalez & Kuenzi, 2012). However, women working in STEM careers in the U.S. represent less than 25%, even though they occupy almost half of the labor force

(Beede, Julian, Langdon, McKittrick, Khan & Doms, 2011). According to the report *Women in STEM: Gender Gap to Innovation*, Beede et al. (2011) stated that of 44 million college graduates with jobs in the U.S., there were only 2.5 million females compared to 6.7 million males with STEM degrees. Of those, only 0.6 million (26%) women and 2.7 million (40%) men worked in STEM jobs. Maintaining and increasing the number of women in STEM fields is vital for initiating scientific innovation, increasing financial growth, and empowering the U.S. to become a global leader in STEM fields (Hill, Corbett, & St. Rose, 2010).

Recognizing this situation, President Barack Obama noted the importance of the presence of more females with STEM majors in the workforce. Soon after his State of the Union Address in February 2013, he said:

> One of the things that I really strongly believe in is that we need to have more girls interested in math, science, and engineering. We've got half the population that is way underrepresented in those fields and that means that we've got a whole bunch of talent . . . not being encouraged the way they need to. (Office of Science and Technology Policy, 2013, para. 1)

Even though scientific research has not validated that inborn differences in terms of scientific and mathematical capabilities exist between males and females, the gender stereotypes against women may prevent females from pursuing STEM careers (National Coalition for Women and Girls in Education, 2012). Research has also proven that negative stereotypes about abilities are major barriers to representation and success of women, minority, and underrepresented groups in mathematics classes (Chen & Soldner, 2013; Gonzalez & Kuenzi, 2012). Therefore, gender stereotypes represent one of the

obstacles in producing more STEM majors from colleges as these stereotypes likely result in the lack of female students pursuing STEM careers
(Hill et al., 2010).

African Americans. Another underrepresented group in STEM education is African American students. In 2011, 11% of the workforce was African American but only 6% held STEM jobs, which was up from 2% in 1970 (Landivar, 2013). According to the American College Testing (ACT) report (2013), comparing students from different races, African American students are less likely to be prepared for college. The United States Department of Education Office of Civil Rights (2014a, 2014b) has published statistics regarding the profound achievement differences in performance of African American high school students and their white counterparts. They have indicated that there are three key areas to consider when preparing students for college. These areas are: the availability of coursework level; the experience of the teachers; and the accessibility of guidance counselors. With regard to coursework, African American students are underrepresented in college preparatory classes and often guided into lower level courses as an alternative to these classes (Moore et al., 2010). For instance, the programs that prepare high school graduates for college were utilized by only 25% of African American students (Palmer, Davis, Moore, & Hilton, 2010). Moreover, many teachers and counselors lower their standards and their expectations due to the presence of negative stereotypes regarding the work ethic of African American students and their families (Bryant, 2015). Many researchers have indicated that the stereotypes of African Americans as being intelligently lower have negatively influenced those students' academic performance (Aronson, Fried, & Good, 2002; McKay, Doverspike, Bowen-

Hilton, & Martin, 2002; Osborne, 2001; Steele & Aronson, 1995). Consequently, one of the major impediments for producing more African American students majoring in STEM fields from colleges and universities is the existence of negative stereotypes about the intellectual abilities of African Americans in the U.S. education system.

Hispanics. Among all minority groups living in the U.S., the Hispanics are the youngest group growing faster than others. The United States Census Bureau (2008) has projected that in several states Hispanics will become the majority group by 2040 and will include 30% of the U.S. population. Although the largest minority group in the public school system is currently Hispanic students, their enrollment level and scores in science and mathematics achievement tests are significantly lower than the national average (NSF, 2014).

Similar to African American students, Hispanic students are underrepresented in college preparatory classes in high school and are not sufficiently exposed to STEM subjects at the K-12 Level. For example, according to the U.S. Department of Education Office for Civil Rights (2014a), the highest percentage of African American and Hispanic students attend high schools that do not offer a second year of algebra, even though two years of algebra are usually required for college-level courses in mathematics and science. Therefore, Hispanic students, similar to African Americans, do not make up a sufficient number of undergraduates and graduates in STEM fields (U.S. Commission on Civil Rights, 2010). The Institute for Higher Education Policy (2010) reported that only16% of college Hispanic students who began as students majoring in STEM in 2004 graduated with STEM degrees by 2009, compared to 25% of Caucasian students. As Astin and Astin (1992) indicated, one of the solutions for graduating more minority students majoring in STEM is to further the capabilities of all students in high school, particularly Hispanics and African Americans in mathematics and science. One of the improvements which can lead to participation of more Hispanic students in STEM fields is to remove the negative stereotypes in academics since these students, like African Americans, have been the target of negative stereotypes (Gonzales, Blanton, & Williams, 2002; Schmader & Johns, 2003). Therefore, the goal of producing more students in STEM majors cannot be accomplished without removing the negative stereotypes, which have had an enormous impact on the participation of underrepresented minorities, including females, African Americans, and Hispanics in STEM fields.

Lack of Motivation

Researchers have indicated that there is an extremely low level of interest among high school students for participating in STEM-related academics (Hossain & Robinson, 2012). Despite students' lack of interest in STEM careers, however, there is a significant need for more workers in the STEM fields (PCAST, 2010). It has been predicted that by 2018, the rate of increase in many science and engineering occupations will be faster than the average pace of all other jobs. Moreover, researchers predict that 9 of the 10 fastest increasing careers that demand at least a bachelor's degree will depend on substantial knowledge of mathematics or science (Lacey & Wright, 2009; National Science Board, 2010; Wang, 2013). Although many researchers have concentrated on how to raise persistence and attainment among students who have chosen to study in STEM fields, there has not been enough study about what inspires and persuades students to enter the STEM pipeline or how we can motivate them to do so (Wang, 2013).

The notion of persistence has its origins in social and cognitive psychology as one of the indicators of motivation (Bandura, 1989). Motivation plays a vital role in learning; it is an internal condition that stimulates, directs, and sustains an individual's conduct (Glynn, Brickman, Armstrong & Taasoobshirazi, 2005). Likewise, the motivation toward learning STEM subjects can be described as an internal condition that stimulates, directs, and sustains an individual's STEM learning performance. According to Druger (2006), one of the most important objectives of instructors is to facilitate students in expanding their interest in learning on their own in college introductory science courses. To this end, Glynn et al. (2005) indicated that in order to help students majoring in STEM to persist and become self-learners, educators need to know what motivates students to major in STEM fields, what emotions they feel as they struggle, and which students lack motivation and why.

Motivation obviously matters in choosing STEM-related fields. Wang (2013) indicated that from the pre-college student's viewpoint, the cornerstone of encouragement to pursue STEM majors is being interested in mathematics, having a positive attitude toward mathematics, and appreciating its significance. The interest in mathematics influences students' later mathematics and science course-taking which, in turn, encourages one's belief of possessing the ability to succeed in mathematics and science courses. This belief, referred to as self–efficacy, along with students' accomplishments in mathematics and science courses in high school, can lead students to choose STEM majors in college (Wang, 2013). Wang concluded that students who feel their high school mathematics and science courses have adequately prepared them for college are more likely to choose a STEM major.

Researchers have identified other variables that can facilitate increasing motivation to study STEM-related disciplines (Beier & Rittmayer, 2009). Utilizing technology such as using specific software or interactive whiteboards is an example of these variables (Fan & Williams, 2010; Hughes & Riccomini, 2011; Isiksal & Askar, 2005; Maki et al., 2006; Torff & Tirotto, 2010). However, many researchers propose that STEM educators in the U.S. have failed to motivate students to attain sufficient abilities and technological skills required in meeting the country's difficult economic and leadership demands (Hossain & Robinson, 2012). Furthermore, it has been reported that 69% of high school dropouts nationwide claimed that the reason for their failure in school was the lack of interest in working hard to succeed (Bridgeland, Dilulio & Morrison, 2006). Therefore, to increase the number of STEM graduates from college, educators may need to use non-traditional instructional methods to engage and motivate students in learning science and mathematics.

Mindset

Many researchers have indicated that there is more to student success than intellectual abilities, program of study, and teaching (Yeager, Paunesku, Walton & Dweck, 2013). The effect of physiological factors identified as non-cognitive factors on students' academic accomplishment can be much more significant than cognitive factors (Dweck, Walton, & Cohen, 2014). Researchers have shown that one of the most important non-cognitive factors influencing students' success is their mindset about intelligence (Dweck & Leggett, 1988; Dweck et al., 2014; Yeager et al., 2013). Some students believe that their cognitive capabilities are essentially unchangeable (i.e., a fixed mindset), which means that they have certain levels of ability with which they are born and nothing can change that. A student with a fixed mindset avoids difficulties, considers effort as useless, disregards valuable negative feedback, gives up easily, and feels intimidated by the accomplishment of others. In contrast, students who have a growth mindset believe that their intellectual abilities can be cultivated and developed through application and instruction (Dweck, 1999). A student with a growth mindset welcomes challenge, perseveres regardless of impediments, learns from errors and critiques, discovers lessons and creativity in the success of others, and perceives effort as the path to mastery. People with a growth mindset are confident that they can improve their talents through tenacity, hard work, and commitment; intelligences and abilities are simply a beginning source (Dweck, 2006).

The concept that hard work and struggle can lead to successful learning is strange to many U.S. students (Stigler, 1999). According to James Stigler, UCLA psychologist and Carnegie Senior Fellow, the lack of faith in the importance of hard work may be rooted deep in the American culture. In the early 1990s, Stigler and his colleagues examined Japanese and Chinese education systems. The goal in one of the studies was to evaluate the reaction to facing academic challenges of first grade students in Japan and the U.S. First graders in this experiment were faced with an impossible mathematics problem created by researchers. U.S. first graders worked on the problem approximately 30 seconds, on average, and then said that they had not worked this kind of problem before. In contrast, the Japanese students, apparently inspired by the challenge, worked calmly on the problem for the whole hour (Stigler, 1999). Stigler concluded that U.S. students characterized struggle as an indication of failure while classifying natural ability as sign of success. However, more than 40 years of scientific research advocates that an excessive emphasis on intellect or ability leaves students susceptible to failure, afraid of challenges, and reluctant to make efforts to learn and improve their shortcomings (Dweck, 2007).

Researchers have shown that many students have a fixed mindset, which has been related to lower grades, especially in mathematics (Yeager et al., 2013). A mathematics educator has explained the probable causes of having many students with a fixed mindset in mathematics classrooms compared to other subjects (Lee, 2009). One of the causes is that many students think of mathematics as limited to getting an answer, which can be either right or wrong. To these students, success in mathematics appears to be based on luck rather than hard work, especially when the student has not had enough time to explore the problem and think about different options. Lee (2009) indicated another cause for having more students with a fixed mindset in mathematics classrooms was the perception that mathematical abilities are innate. She argued that when a student demonstrates a superior performance in mathematics compared to others, it supports the idea in students with a fixed mindset that their classmate is born with mathematical abilities, and the accomplishment is not related to hard work and effort. Therefore, to improve the number of students majoring in STEM fields, it is essential that students realize the importance of hard work and learn to welcome and accept challenges with a growth mindset.

Background of Study

This study was designed to address some of the previously mentioned obstacles for improving the quality and quantity of STEM graduates from colleges and universities. There were many factors that played a vital role in achieving the objective of this study.

Some of the factors related to the study were: the uniqueness of the reformed classroom, the importance of the first year in college, the significance of the first mathematics course, and the importance of examining two non-cognitive factors such as students' motivation and mindset. Each of these aspects is explained in the following sections.

The Unique Feature of Reformed Classrooms

In traditional classrooms, much of the authority comes from what the teacher says (Hiebert, 1999; Stigler & Hiebert, 1999). Following a behaviorist approach, traditional mathematics teaching primarily focuses on memorizing facts, performing procedures, following the rules, and substituting values in formulas (Hiebert, 2003). In contrast, reform teaching focuses on a constructivist perspective in which discussion takes place regularly as students work together to discover the principles behind the mathematics. The philosophy of these two approaches in acquiring knowledge is quite different. Behaviorism highlights students' passive duplication of the witnessed behaviors whereas constructivism states that students consider a new task with previous knowledge, integrate new information, and, then, create their own meaning (Orey, 2002). In mathematics, this active form of learning includes problem solving, reasoning, drawing connections, communicating, and using multiple representations (NCTM, 1989, 2000). The main focus in traditional mathematics classrooms (i.e., the rote memorization of rules and facts without gaining conceptual understanding) has not motivated students to learn mathematics (Silva & White, 2013). Therefore reformed classrooms were chosen for their unique features to support the objective of this study: improving the quality and quantity of students majoring in STEM fields.

The Importance of the First Year in College

This study concentrated on the first year of college since according to the National Academy of Engineering (NAE, 2005) the freshmen year of college is a crucial year as it signals pass or fail time for students. In their report to the U.S. Department of Education, Chen and Soldner (2013) indicated that performance of those students who persisted as STEM majors was heavily influenced by their first year in college, as this first year set the tone for the following years. Cataldi et al. (2011) also indicated the first year of college as the most critical year, which will influence a student's entire college experience.

The Significance of the First Mathematics Class

The initial mathematics class for students majoring in STEM fields is often pre-calculus (Post et al., 2010; Yantz, 2013) and is a critical component in their first year of study (Chen & Soldner, 2013). According to researchers, the performance of students majoring in STEM fields in entry-level classes is the main predictor of their persistence in STEM fields (Ost, 2010; Rask, 2010). Therefore it is extremely important for these students to succeed in their first mathematics course in college (Wang, 2013). This was one of the main reasons for the significance of mathematics classrooms. Recognizing that in mathematics classes students generally have a fixed mindset and are less motivated in learning mathematics than any other subject (Feldman, Waxman, & Smith, 2014; Yeager et al., 2013), this was another important factor for the significance of the mathematics course in this study. Therefore students' success in pre-calculus was one of the factors that played an important role in accomplishing the goal of this study.

Motivation and Mindset

To focus on decreasing STEM attrition is one of the inexpensive methods to increase the number of graduates in STEM fields (Ehrenberg, 2010; Soldner, Rowan-Kenyon, Kurotsuchi Inkelas, Garvey, & Robbins, 2012; Yantz, 2013). Nevertheless, the non-cognitive factors that have not been the focus on most of the studies can significantly promote success and improve STEM education (Dweck et al., 2014; Yeager et al., 2013). These psychological factors often involve students' individual beliefs and strategies that have developed over time, such as motivation, self-determination, self-efficacy, and mindset.

Problem Statement

The impediments for producing more students majoring in STEM fields in higher education are enormous and complicated. Despite the significance of the issue influencing the future of the next generation, there has not been a definite solution for this problem. There have been numerous studies on different strategies to improve STEM retention and graduation rates (e.g., Chen & Soldner, 2013; Thomasian, 2011). One potential strategy involves engaging students in non-cognitive intervention activities. However, there has not been a study at the college level in a reformed, pre-calculus classroom utilizing non-cognitive intervention factors for motivation and mindset of students majoring in STEM fields.

Purpose of the Study

The purpose of this mixed-methods study was to examine the influence of motivation and mindset interventions on students majoring in STEM fields for enhancing and improving students' success in their pre-calculus course. The following research questions were addressed:

1. Do students in a reformed class who receive motivation and mindset interventions perform significantly better on a pre-calculus achievement test compared to students in a similar class who do not receive such interventions?
2. Do students in a reformed class who receive motivation and mindset interventions show significant improvement in motivation towards mathematics compared to students in a similar class who do not receive such interventions?
3. Is there a difference in the proportion of students in groups with either a growth or a fixed mindset depending on condition at post-test? Does the proportion of students in the experimental group change from a fixed vs. a growth mindset from pre-to post-interventions?
4. How do individuals of different mindset and/or motivation benefit, if at all, from the interventions?

Significance of the Study

The significance of this study was its ability to provide insight into the interventions necessary to support the success of students majoring in STEM fields in their initial mathematical experience in college. This study was conducted in pre-calculus classes, often the first mathematics course in college for students who major in STEM fields, which is a critical component in their freshman year and is the main predictor of their persistence in STEM disciplines (Ost, 2010; Rask, 2010). The knowledge of using the interventions in this research (e.g., motivation and mindset) not only will influence how mathematics educators teach, but will also influence the entire education system.

These interventions featured in the study, which were inexpensive to use, have promoted student achievement in other settings (Dweck et al., 2014). Therefore, policy makers in education could invest in these interventions to help students majoring in STEM to succeed in college.

Definition of Key Terms

The following definitions of key terms will enable the reader to better understand the context of this study.

STEM Fields

The term STEM Fields is used to describe the STEM-related majors offered at the institution for this study. These majors include: Biology, Chemistry, Biochemistry, Geoscience, Physics, Computer Science, Engineering Technology, Mechatronics Engineering, Environmental Science and Technology, Mathematics, and Statistics.

Mindset

Mindsets are views that people adopt about themselves and can have profound consequences on all aspects of their lives (Dweck, 2006). People with a *fixed mindset* believe that their cognitive capabilities are essentially unchangeable; whereas people with a *growth mindset* believe their abilities can be developed through their perseverance and effort.

Motivation

The Latin verb *movere* is the root of the word *motivation*, which means to move (Ushioda, 2011). According to Paulsen and Feldman (1999), motivation is the factor that directs and energizes the behavior of humans and other organisms.

Chapter Summary

The demand for college graduates in STEM majors continues to grow, as it supports the U.S. in maintaining its worldwide competitiveness in STEM. For postsecondary educators, however, there are many problems and obstacles to increasing the quality and quantity of STEM majors. Some of these obstacles include: the lack of qualified teachers in K-12 education; low performance of students in worldwide competitions in science and mathematics; low participation of females, African Americans and Hispanics students in STEM majors; lack of students' motivation; and students' mindsets. This study was meant to overcome some of the mentioned obstacles by utilizing interventions for two non-cognitive factors (i.e., students' motivation and mindset) in a reformed pre-calculus classroom. There were many factors that contributed to the uniqueness and importance of this study. These included: the unique features of conducting the study in a reformed classroom as opposed to a traditional classroom, the importance of first year in persistence of STEM majors, the significance of the first mathematics course which is often pre-calculus for all STEM majors, and the importance of examining and utilizing interventions for two non-cognitive factors (i.e., motivation and mindset).

CHAPTER TWO: LITERATURE REVIEW

Introduction

The National Science Board (2010) has declared that the enrollment of freshmen college students in STEM majors is alarmingly low. For example, during the academic year 2007-2008, only 14% of all undergraduates in U.S. colleges and universities majored in STEM (Snyder & Dillow, 2011). This statistic exists despite the report indicating that one-third of all freshman students had expressed interest in STEM majors before entering college (Chen & Soldner, 2013). To emphasize the importance of STEM education, the former president of the Massachusetts Institute of Technology, Charles Vest, cautioned:

> America faces many challenges . . . but the enemy I fear most is complacency. We are about to be hit by the full force of global competition. If we continue to ignore the obvious task at hand while others beat us at our own game, our children and grandchildren will pay the price. We must now establish a sense of urgency. (STEM Resource Guide, n.d., para. 5)

Despite a high demand for successful competition in the worldwide economy, many obstacles create impediments to producing more skillful students majoring in STEM fields (PCAST, 2012). To improve students' academic success, many educators consider non-cognitive factors such as motivation and mindset to be far more significant than cognitive factors (Dweck et al., 2014; Lee, 2009; Silva & White, 2013). Given the need for improving the quality and quantity of STEM graduates from colleges and universities, the purpose of this study was to examine the influence of motivation and mindset interventions on students majoring in STEM fields for enhancing and improving students’ success in their pre-calculus course. With a focus on non-cognitive factors, this chapter will start with a literature review on the effort made to improve student motivation. The next section will review studies on student mindset, followed by a chapter summary.

Motivation

Motivation as a concept includes an inter-connected collection of beliefs, insights, values, pursuits, and activities (Lai, 2011). The Latin verb *movere* is the root of the word *motivation* which means to move (Ushioda, 2011). The study of motivation and motivational theories attempts to reveal what energizes individuals to move and what kind of tasks and activities individuals move toward (Pintrich & Schunk, 2002).

Many unmotivated and under-motivated students attend college every year, posing challenges and frustration in the classroom (Mobbs & McFarlane, 2010). Researchers have shown that there is a fairly constant association between motivation and achievement in mathematics (Broussard & Garrison, 2004; Gottfried, 1990; Lange & Adler, 1997). Therefore, student motivation is a crucial requirement in preparing students for college, the labor force, and lifetime learning. What follows is a literature review of theoretical methods that have been utilized to study and assess student motivation.

Theoretical Methods

In early literature, extrinsic reinforcement appeared as the initial method to study motivation (Stipek, 1996). An American psychologist, B. F. Skinner, was a pioneering advocate of extrinsic reinforcements. He argued that behavior followed by a pleasant outcome was reinforced and often repeated while behavior followed by an unpleasant outcome was not reinforced and was likely to discontinue (Skinner, 1938). When applying this perspective in the classroom setting, the teacher had to use praise and good grades to reward desired behavior and impose loss of benefits or bad grades as punishment to undesired behavior. However, the behaviorist approach of reward and punishment showed that it was not successful for all students and it could not impact more internal behaviors, such as paying attention (Stipek, 1996).

According to Stipek (1996), due to these limitations of extrinsic reinforcement, new approaches such as Cognitive Behavior Modification (CBM) were created to increase motivation. The focus of CBM was on adjusting an individual's thinking in order to modify his emotions and behaviors (Corey, 1991; Harris, 1988). Teaching each individual to supervise his behavior, establish his objectives, and reinforce them personally was the goal of CBM. To utilize this method, teachers had to encourage students' cognitive processes to modify their thinking as well as their behavior. Like the extrinsic reinforcements, however, this method had disadvantages. Researchers reported that when utilizing the CBM method, some students were dishonest by either rewarding themselves excessively or establishing low performance benchmarks (Lai, 2011; Speidel & Tharp, 1980).

In the late 1960s and 1970s, the next period in the literature of motivation emerged. The most important change in this timeframe was the general shift away from mechanism to cognition (Graham & Weiner, 1996). The emerging theory during this period regarded motivation as a concept controlled by what one expects to get and the chance of actually getting it. The emerging theory, titled the expectancy-value theory, was put forth by Atkins and Rotter, and it dominated the study of motivation for 20 years, from the early 1960s to 1980. Under the well-accepted expectancy-value theory, cognition was deemed to play a vital role in motivated behavior. Consequently, the important dependent variables in motivation became choice and persistence (Graham & Weiner, 1996).

Many contemporary researchers also believe that cognition and motivation not only influence each other but also jointly affect academic success. Consequently, both are influenced by the social perspective of learning (e.g., Linnenbrink & Pintrich, 2002; Pintrich, 2003). Carrying the role of cognition to its logical end, the main direction in motivational theories in the next era was the study of one's self. Self-efficacy, self-worth, self-handicapping, and self-focus were some of the topics dominating the field of motivation (Graham & Weiner, 1996). Another important trend worthy of mentioning was the broad classification of motivation theories into two perspectives of *content* and *process*. Several theoreticians including Maslow, Alderfer, Herzberg, and McCelland investigated motivation with a content perception, which deals with *what* motivates people and is therefore focused on individual necessities and goals. Other scholars such as Vroom, Porter, Lawler, Adams, and Locke viewed motivation with a process perspective in mind, which focused on *how* motivation occurred (Ozgur, 2011).

Finally, temporal motivation theory (TMT) is a recent approach to motivation study (Steel, 2007). This method draws on other important motivational theories, including Self-Efficacy, Incentive Theory, Need Theory, Drive Theory, and Goal Setting. This theory suggests that people will most likely postpone any job that is unpleasant now and offers benefits only in the faraway future. In other words, people are more likely to delay high-priority tasks if there are possibilities available for the jobs that are instantly enjoyable. Steel (2007) presented the following formula for motivation under the TMT:

$$Motivation = \frac{Expectancy \ * \ Value}{1 + Impulsiveness * \ Delay}$$

where, Motivation is the wish for a certain consequence, Expectancy or self-efficacy is the probability of success, Value is the incentive associated with the outcome, Impulsiveness is the individual's sensitivity to delay, and Delay is the time to realization. The model theorizes that procrastination is strongly associated with Expectancy, meaning that individuals with low self-efficacy are more likely to procrastinate. Moreover, that procrastination is strongly related to Delay, suggesting the closer an individual is to realizing a goal, the harder he works for it.

Following the same theoretical framework of studying one's self, many researchers (e.g., Pintrich, 2003; Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011) have developed instruments to assess students' motivation in college. The conceptual framework of Pintrich's study was based on a self-regulatory (SRL) perspective on student motivation and learning, in which learners are considered as active participants in the learning process. In 1991, Pintrich and his colleagues designed an instrument to assess students' motivation in college courses, called the Motivated Strategies for Learning Questionnaire (MSLQ). Glynn and his colleagues (2011) also have attempted to examine and assess what motivates students in learning science in college. The researchers constructed a questionnaire designed to assess: intrinsic motivation, self-efficacy, self-determination, grade motivation, and career motivation of students toward learning science in college. In this period, scholars such as Eccles and Wigfield (2002) predicted that researchers will still concentrate on incorporating cognition, motivation, and self-regulation as a central topic for motivation for the next ten years.

Finally, motivation researchers have studied in depth the reasons why a person decides to participate or not in a task. The reasons are related to how an individual's values, beliefs, and goals are linked to their accomplishment behaviors (Eccles & Wigfield, 2002). To shed more light on individual beliefs and their relation to achievement behavior, neuroscience is beginning to play a key role in creating new perspectives in several fields including motivation (Beer, 2012). The role of neuroscience in studying motivation is crucial as it opens up a new perspective which seeks to understand how an individual's beliefs, values, and goals are related to their cognitive control (Botvinick & Braver, 2015).

The journey in the study of motivation started from a behaviorist perspective in which extrinsic reinforcement dominated the educational field. As theories of motivation in education progressed, the role of various factors such as cognition, self, and neuroscience became evident. Future works on the subject will continue to open new horizons into the complex issue of motivation and its effect on learning and academic achievement of students.

Mindset

For many decades, researchers have held an individual's mindset as an essential factor in comprehending human behavior (Burnette, O'Boyle, VanEpps, Pollack, & Finkel, 2012). Dweck and colleagues at Stanford University have discovered a relationship between the students' viewpoint of intelligence and how they interpret and respond to academic setbacks (e.g., Dweck, 2006; Dweck & Leggett, 1988; Molden & Dweck, 2006; Yeager & Walton, 2011). These researchers found that the students who believed their intelligence to be unchangeable (i.e., fixed mindset or *entity theory of* *intelligence*) were more likely to experience academic setbacks compared to the students who believed that intelligence could be improved with hard work and effort (i.e., growth mindset or *incremental theory of intelligence*). The researchers concluded that students with a fixed mindset attributed academic setbacks to a lack of talent and their response was to withdraw efforts, feel helpless, and give up. In contrast, students with a growth mindset viewed academic setbacks as an outcome of inadequate effort or weak strategy, and their response was to increase their effort, seek help, or use a better strategy.

Bandura (1997) described people with a fixed mindset as individuals who believe that their ability is innate, manage to prevent difficult tasks, and avoid revealing failings even at the cost of learning. In contrast, Bandura (1997) described individuals with a growth mindset as those who believe ability can be acquired and consider challenges and obstacles as a suggestion that more effort or better strategies are required to become successful. Individuals with a growth mindset possess persistence, which in addition to intensity and direction is one of the three key elements in exhibiting successful motivation (Meer, 2013). Therefore, a growth mindset is strongly linked to successful motivation (Dweck, 1999). In the following section, the history of how studies on mindset emerged, how to examine an individual's viewpoint of intelligence, and the interventions used to change students' mindset will be presented.

Studies on Mindset

Interestingly, research history on human mindset started as animal science research. In the late 1960s, a graduate student studying animal motivation at Yale University noticed that the laboratory animals sometimes quit what they were capable of doing after confronting many failures (Krakovsky, 2007). The predominant topic in animal research at that time was *learned helplessness* and the suggested cure was to offer the animals a continuous sequence of success. Soon after, the focus of this graduate student's research shifted to the reaction of humans in similar situations. The developing research questions were: "What is the difference between a fully capable child who gives up when confronted with a failure and another child who is motivated by failure? What is the difference between a powerless reaction and its converse, the willpower to learn new skills and overcome obstacles?" (Krakovsky, 2007, p. 1). This is how Dweck came to choose her dissertation topic (Krakovsky, 2007).

Soon after, Dweck and Reppucci (1973) found that individuals who related their failure to a lack of ability became discouraged, felt helpless, and gave up. However, people who believed that they had exerted enough effort even after facing failure were encouraged by challenges. Dweck conducted an experiment with students who had been labeled helpless by the school personnel. When these students were confronted with difficult mathematics problems, they were not able to solve the problems that they had solved before. After teaching and encouraging the experimental group to persist in the face of failure and redo the problems, the group showed improvement compared to the control group, which had not received any encouragements. In 1975, Dweck presented her study in an article titled, "The Role of Expectations and Attributions in the Alleviation of Learned Helplessness," which has become one of the most cited articles in modern psychology.

One of the main areas in psychological research at that time was attribution theory, which explored how people made attributions. This theory is related to an individual's belief about the reasons behind events and behavior of others. According to

Stanford psychology professor Lee Ross, Dweck made practical use of the attribution theory by asking why people's beliefs are important (Krakovsky, 2007).

The first major area of Dweck's work was to show the effect of her theory of intelligence on the student's academic performance. Elliott and Dweck (1988) observed that when students encountered setbacks, they displayed different outcomes depending on their mindset. The study showed that even when comparing students with equal intellectual ability, the students' responses to academic challenge were influenced by theories of intelligence. In this research, participants of different mindsets were allowed to select tasks at various levels of difficulty. Then, the researchers assessed a variety of factors, including the students' reactions to criticism, choice of task, performance, perceptions about performance, persistence, and level of helplessness. The results showed that participants with a fixed mindset tended to relate success or failure to their ability or lack of ability, chose easy tasks, showed helplessness when confronted with setbacks, and focused less on learning and more on performance and success. However, participants with a growth mindset were more likely to relate success or failure to their lack of effort or strategy, show persistence or mastery-oriented behavior when faced with challenges, and emphasize learning rather than competition.

The second leading area of Dweck's research concentrated on the practice of praises and criticisms. Mueller and Dweck (1998) investigated using praises that complimented the students on their ability (e.g., "You must be really smart") or their hard work and effort (e.g., "You really worked hard on this"). Their results indicated that even though praising a participant's ability may make the recipient feel good in the short term, it could be damaging when a setback occurs. In similar studies, researchers indicated that praising students on their abilities might lead them to believe that the setback happened because they lacked ability or intellect (Dweck, 1999; Kohn, 1993). Under the same rationale, researchers caution parents and educators against wording an ability-based criticism, especially for younger and more sensitive individuals (Dweck, 2007). In contrast to ability-based feedback, praising students on their effort promoted persistence and helped maintain their future accomplishments when encountering challenges and setbacks (Dweck, 2007).

One of the recent studies on mindset by Blackwell, Trzesniewski, and Dweck (2007) concentrated on low-achieving seventh graders in a mathematics class. In that study, both the experimental and the control group learned about study skills and the brain. A key concept that was introduced in the experimental group but not the control group was that intelligence is like a muscle, and it grows stronger through exercise and usage. At the conclusion of the study, the researchers found that even though the control group had all but one of the interventions that the experimental group received, they did not show any improvements. However, learning about a growth mindset in the experimental group increased those students' motivation and mathematics grades (Blackwell et al., 2007).

More than 40 years of research on mindset has demonstrated that individuals with a growth mindset tend to be more successful in all aspects of life (Dweck, 2006). This finding has important implications on education, as illustrated by the studies in this section. Students need to be informed that intelligence is incremental in order to promote a growth mindset. To achieve that end, appropriate interventions should be implemented, which could include asking students to give a short presentation or read an article on the subject. This effort can have considerable productive influence on student accomplishment (Dweck, 2006).

Chapter Summary

STEM educators have made many attempts to promote the quality of learning and increase the number of STEM majors in college. The majority of the research that relates to this important issue concentrates on examining cognitive factors such as the students' high school grade point average and ACT scores. However, recently many educators and researchers have found non-cognitive factors, such as motivation and mindset, to be far more significant than cognitive factors.

These two non-cognitive factors are very much connected, and in fact, the study of mindset emerged from investigating motivation and its attributes. In order to gain motivation toward performing a task, the growth mindset rather than a fixed mindset is required. To that end, the belief of students about intelligence is a key factor and can make a difference in their performance when faced with obstacles, challenges, and setbacks. One of the major issues for educators in classrooms is that students with a fixed mindset do not have enough persistence to struggle through and complete a task or a problem that may look hard or different from what they experienced before. Learning and admitting that intelligence is incremental and that failure is the stepping-stone for success is a much-needed lesson that will enrich the students' academic and personal lives. With the proper motivation and mindset interventions, the students will learn that persistence and effort is the key to academic success.

CHAPTER THREE: METHODOLOGY

Introduction

There are major concerns that the U.S. is losing its supremacy and competitiveness in science and technology worldwide (PCAST, 2012). Consequently, there is a great demand for students graduating in STEM fields. There are numerous obstacles, however, to increasing the quality and quantity of students who graduate from colleges and universities majoring in STEM fields (e.g., Gonzalez & Kuenzi, 2012; Hossain & Robinson, 2012). The first year of college is crucial in the life of a student entering a STEM major (Chen & Soldner, 2013), and researchers have concluded that the students' experiences in their early mathematics courses are extremely important, as these courses have a significant influence on their future STEM education (e.g., Adelman, 1998; Marshall, McGee, McLaren, & Veal, 2011; National Science Board, 2007; Wang, 2013). In terms of the students' academic success, psychological factors (i.e., non-cognitive factors) such as motivation and mindset have often shown to be far more significant than cognitive factors (Dweck et al., 2014; Lee, 2009; Silva & White, 2013).

The purpose of this mixed-methods study was to examine the influence of motivation and mindset interventions on students majoring in STEM fields for enhancing and improving students' success in their pre-calculus course. This chapter will begin with an overview of the research, context of the study, and study participants. It will follow with a description of the instruments and data sources used in this study. Next, the procedures that were utilized in this study and the data analysis procedures will be provided. In conclusion, the limitations and delimitations of the study and the chapter summary will be presented.

Research Overview

This study used a mixed methods design, which took advantage of both quantitative and qualitative methods. Quantitative approaches are designed to collect numbers and qualitative methods are designed to collect words. The rationale for using this approach was that neither quantitative nor qualitative methods, if utilized alone, were adequate to describe the various aspects of this study. More specifically, quantitative research does not sufficiently examine the personal stories of participants or deeply explore the viewpoints of individuals. Alternatively, qualitative research also falls short of addressing all of the research questions in this study because it does not enable the researcher to generalize from a small group of participants to a large population (Creswell, 2015). The mixed methods design focused on understanding the research problem more completely by collecting and analyzing data, using both quantitative and qualitative methods, in a single study (Creswell & Plano Clark, 2007).

In this mixed methods study, to further explain the research questions, qualitative data was added to quantitative statistics to understand the experiences of students during and after the interventions. The research questions for this study were as follows.

1. Do students in a reformed class who receive motivation and mindset interventions perform significantly better on a pre-calculus achievement test compared to students in a similar class who do not receive such interventions?
2. Do students in a reformed class who receive motivation and mindset interventions show significant improvement in motivation towards mathematics compared to students in a similar class who do not receive such interventions?

3. Is there a difference in the proportion of students in groups with either a growth or a fixed mindset depending on condition at post-test? Does the proportion of students in the experimental group change from a fixed vs. a growth mindset from pre-to post-interventions?
4. How do individuals of different mindset and/or motivation benefit, if at all, from the interventions?

The research design which aimed to answer questions posed as *how* or *why* led to the use of case studies. This was because *how* or *why* questions handle situations that need to be tracked over time rather than explored as simple occurrences or frequencies (Yin, 2014). Therefore, case studies were appropriate to examine how individuals of different mindsets and/or motivations benefited, if at all, from the interventions. In the following sections, the type and the design of the study are described in terms of three categories: explanatory case design, multiple case design, and intervention design.

Explanatory Case Study

Qualitative research is intended to explore and understand the significance individuals or groups attribute to a social or human problem (Creswell, 2009). The qualitative component of the study, which was collected throughout the study, was a multiple case study. Case study is defined as an in-depth investigation of a single person, group, event, or community (Creswell, 2013). Using mixed methods design, an explanatory case study is intended not only to investigate and explain the outcomes but also to explain causal relationships and to develop theory (Yin, 2003).

This study utilized an explanatory case study to investigate how participants of various mindsets and /or motivations benefitted, if at all, from the interventions utilized in the study. This approach was used to describe and interpret quantitative results by collecting and analyzing follow-up qualitative data, which can be valuable when unpredicted results appear from quantitative study (Morse, 1991). To that end, the researcher selected participants and gathered qualitative data in the forms of interviews, written reflections, and observations to help explain the quantitative results.

Multiple Case Design

To answer the research questions, a multiple case design was utilized. The rationale for using a multiple case study over a single case was that results from a multiple case study are often more comprehensive, and therefore the results of the study, as a whole, are considered more robust (Yin, 2009). Furthermore, a multiple case study can provide and illuminate useful information about the differences among the participants (Yin, 2009). In this study, four participants were used in a multiple case study: one with a fixed mindset and low motivation toward mathematics; one with a fixed mindset and high motivation toward mathematics; one with a growth mindset and low motivation towards mathematics; and one with a growth mindset and high motivation towards mathematics.

Intervention Design

According to Creswell (2015), once the basic design of the mixed methods study has been determined, other research designs need to be added in order to build an advanced mixed methods research design. Three widely utilized designs that often appear in mixed methods literature are intervention design, social justice design, and multistage evaluation design. This study utilized an intervention mixed methods design. The goal of this design is to study a research question by implementing an experiment or an intervention and then combining the quantitative result with qualitative data (Creswell, 2015). The researcher used the quantitative data to purposefully select the participants before interventions, conducted classroom observations while paying close attention to the participants before and after implementing interventions, and conducted one-on-one interviews with the case study participants after the post-test results were obtained. Figure 1 illustrates how qualitative data was used throughout the study.

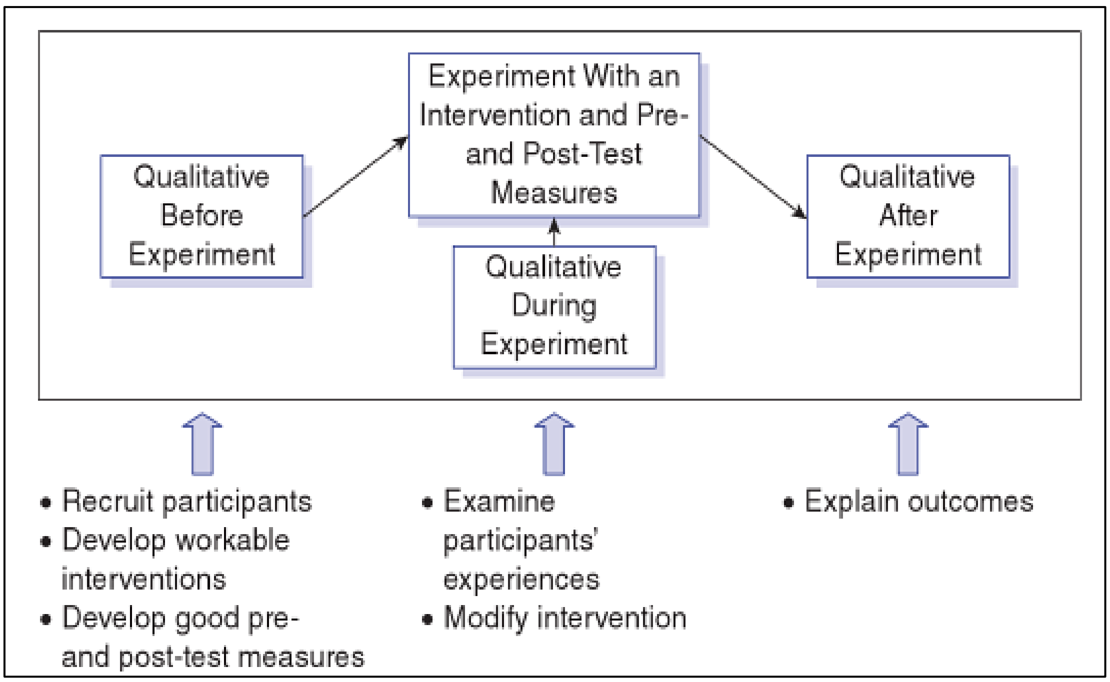

Figure 1. Illustrating how qualitative data is used before, during, and after the Intervention Design. Reprinted from A Concise Introduction to Mixed Methods Research (p. 44), by J.W. Creswell, 2015.Los Angeles: Sage. Copyright 2015 by Sage. Reprinted with permission.

Research Context

This study was conducted at a public university in the southeastern region of the United States. The university's mathematics department believes that the fundamentals of modern society rest on mathematics and problem solving. Therefore, in order to provide its students with practical knowledge and equip them with the tools to succeed in the complicated high-tech world, the university offers mathematics instruction that promotes critical thinking, innovation, and problem solving. Specifically, the mathematics department, which continues to utilize the latest research findings for improving mathematics education, launched a proactive movement, offering students the opportunity to enroll in reformed pre-calculus classrooms. The student-centered or reformed mathematics classroom is entirely different from a traditional one, since it emphasizes communication and problem solving, rather than rote memorization of mathematical rules and facts.

This university serves primarily traditional, full-time students with the average age of 19 years for first-time, freshmen students. In Fall 2015, the number of full-time freshmen males who enrolled at the university was 1,322, which accounted for about 47% of the total entrees, while 1,571 full-time freshmen women made up the remaining 53%. Approximately 23% of all freshman students who joined the university in Fall 2015 declared STEM (i.e., biology, chemistry, computer science, engineering technology, geosciences, mathematics, and/or physics/astronomy) as their major. Even though more freshmen women than men enrolled at the university, only 39% of females declared STEM as their major compared to 61% of male students. Among students who declared STEM as their majors, approximately 58% were white, 28% were African American, and 6% were Hispanic. In Fall 2015, the university offered 26 sections of pre-calculus, which is often the first mathematics course that freshmen students majoring in STEM complete.

Participants

In Fall 2015, two sections of a reformed pre-calculus course with the same instructor were considered for this study. One section was selected as the experimental group with 30 students and the other as the control group with 31 students. The selection was made according to the students' scores on the mindset and motivation pre-tests. The section with lower scores in both areas was assigned as the experimental group. The participants were taking their first mathematics course at the university, and the make-up of the experimental and the control groups closely resembled that of the university. In addition, to help explain the quantitative data, four students were purposefully selected from the experimental group to serve as the cases within the case study. Selection of the four students was based on the two factors of mindset and motivation toward mathematics.

Instruments and Data Sources

The mixed methods study utilized both quantitative and qualitative approaches in gathering data to answer the research questions. When using the quantitative method, four instruments were utilized: the Student Background Survey, the Pre-calculus Concept Assessment (PCA), the Science Motivation Questionnaire II (SMQ-II), and the Mindset Survey. To further explore the research questions beyond statistical trends of quantitative data, qualitative data were collected in the form of interviews, observational notes, and written reflections. In addition, the researcher served as an instrument in the study. In the following paragraphs, each of these instruments and data sources is described.

Quantitative Instruments

Student background survey. This survey asked all participants in this study to share their basic background information with the researcher. This survey (see Appendix A) contained 10 questions requesting general information such as age, gender, major, etc.

Pre-calculus Concept Assessment (PCA). The PCA (see Appendix B) is an instrument designed to assess students' understanding and reasoning abilities required for learning fundamental ideas of pre-calculus (Carlson, Oehrtman, & Engelke, 2010). This instrument consisted of 25 questions with five-choice answers. The authors of this instrument have been evaluating and improving the questions and every answer choice over the past 15 years. Carlson et al. (2010) have used qualitative methods to discover the students' exact misconceptions leading to the wrong choices. They have identified the students' misconceptions by conducting interviews in which they have asked the students to explain their thinking that led to their answer choices. The process of creating and validating the PCA has been supported by the approach of Lissitz and Samuelsen (2007).

The authors reported a Cronbach alpha of 0.73 for the 25-item test, which indicates that the instrument is consistent overall to some degree (Carlson et al., 2010). Results from studies using the PCA have suggested that the instrument is highly predictive, since 77% of students who score 13 (out of 25) or higher on this calculus readiness exam passed Calculus I with a grade of C or better (Carlson et al., 2010). In addition, the authors of the PCA have used this instrument for assessing the effectiveness of a redesigned college algebra classroom compared to a traditional instruction class. They concluded that the PCA was able to detect shifts in students' understanding relative to the overall PCA score (Carlson et al., 2010).

Participants in both sections of the reformed pre-calculus class were asked to complete the PCA so as to assess the participants' understanding and reasoning abilities in their first college mathematics course.

Science Motivation Questionnaire II (SMQ-II). The SMQ-II survey (Glynn et al., 2011) measures students' motivation toward mathematics. Originally designed as a science motivation questionnaire, Glynn et al. (2011) have extended the permission of using versions in which the word biology, chemistry, or mathematics has been substituted for the word science in the questionnaire. Therefore, the SMQ-II was used to better understand the motivation of participants towards learning mathematics.

This questionnaire (see Appendix C) consisted of five components, defined by Glynn et al. (2011). The first component is *intrinsic motivation,* which refers to the innate pleasure of learning mathematics for its own sake. The second component is *self-efficacy,* which involves an individual's confidence in his/her ability to learn mathematics well. *Self-determination* is the third component and refers to the control that an individual believes to have over learning mathematics. The fourth component, *grade motivation*, involves an extrinsic motivation of learning mathematics as a drive for good grades. *Career motivation* refers to learning mathematics as rationale to gain a tangible end, such as a career.

This instrument had 25 items, five items from each component, using a 5-point Likert scale (0-4 points for each item). Therefore, the total points obtained from each component ranged from 0 to 20. According to Glynn et al. (2011), the reliabilities (i.e., internal consistencies) of the scales, measured by Cronbach's alphas, are: career motivation (0.92), intrinsic motivation (0.89), self-determination (0.88), self-efficacy

(0.83), and grade motivation (0.81). The Cronbach's alpha of all 25 items is 0.92. The SMQ-II was selected for this study since the Cronbach's alpha of the test items was over .90, indicating strong reliability for the instrument.

Mindset Survey. The mindset survey (see Appendix D) consisted of six items, using a 6-point Likert scale. The first three items were used to assess students' mindset about intelligence, whether they perceive it as fixed or can be increased through instruction and effort (Dweck, Chiu, & Hong, 1995). This survey has high internal reliability for the implicit theory of intelligence; it ranges from .94 to .98. Similarly, the next three items were created to evaluate students' mindset about mathematical ability (Willingham, Barlow, Stephens, Lischka, & Hartland, 2016). It was important to include these additional three items because Willingham and colleagues reported that mindset regarding intelligence and mathematical ability represent different constructs. For example, an individual may hold a growth mindset about mathematical ability but a fixed mindset regarding intelligence. Although the form and use of the last three items was supported by Dweck and Leggett (1988), their reliability or validity had not been tested.

Two scores were obtained from this survey: the participants' mindset toward intelligence and learning mathematics. To score each part, the points related to the three items were averaged (ranging from 1 to 6) where lower scores indicated a growth mindset toward intelligence/learning mathematics. The criterion reported by Dweck and colleagues (1995) were used for classifying mindsets in this study. According to this classification participants with an overall score of 3.00 or lower were identified as having a growth mindset toward intelligence/mathematical ability and as a fixed mindset if their overall score was 4.00 or higher.

Qualitative Instruments

In a case study, the researcher investigates a real-life contemporary case over a continuous period of time collecting various data, including observations (Creswell, 2013). To examine how students of varying motivations and/or mindsets benefit, if at all, from the interventions, several qualitative instruments were used. They consisted of observational notes, one-on-one interviews, written reflections, and the researcher. A description for each of these follows.

Observational notes. Yin (2009) indicated that in qualitative research, observations are one of the most powerful tools since they enable the researcher to collect multiple forms of data, which consequently allows for data triangulation. In this study, the researcher observed the case study participants at the class's regular instruction time from 11:30 a.m. to 12:25 p.m. before and after interventions and took observational notes pertaining to the fourth research question (see Appendix E). These observational notes included the case study participants' reactions to the interventions.

One-on-one interviews. The interviews were designed to explore and reveal case study participants' perceptions of how they benefitted, if at all, from the interventions. The researcher conducted structured interviews, which enabled her to explore and ask clarifying questions to uncover the participants' perceptions before interventions (see Appendix F) and at the end of the Fall 2015 semester after the post-tests (see Appendix G). The interviews were audio recorded and transcribed later for analysis.

Written reflections. All participants had a chance to write several reflections on their experience during the interventions. There were two written reflections related to motivation (Appendices H & I) and two related to mindset (Appendices J and K).

Furthermore, the case study participants were asked to reflect on their experience after the interventions by responding to the questions in Appendix L.

The researcher. According to Creswell (2013), the researcher served as an instrument in this study. The qualifications of the researcher are presented to confirm credibility. The researcher had extensive experience teaching mathematics in the U.S. and internationally. The researcher's international teaching career consisted of teaching high school mathematics and undergraduate university mathematics courses for a total of five years. The researcher also taught various undergraduate university courses in the U.S., including college algebra and pre-calculus for almost a decade before returning to school to pursue a Doctor of Philosophy in Mathematics and Science Education. The researcher had successfully completed a qualitative research course and had used her expertise in coding students' written reflections in an externally funded project at the university. The researcher's capabilities qualified her to serve as an instrument in this study.

Procedures

In this section, the procedures for collecting data are described. After the approval of the study, an application for Institutional Review Board (IRB) was submitted (see Appendix M). After obtaining IRB approval, the data collection started in Fall 2015.

The procedures for the study were organized into three phases. The first phase of this study occurred before implementing interventions. The second phase consisted of activities during the implementation of interventions, and the third phase focused on procedures that took place after the interventions. Each phase is described below.

Phase I: Prior to Interventions

During the first week of classes in the Fall Semester 2015, students in both the experimental and control groups were invited to participate in the study. As a requirement for the class, students were asked to go to the university's testing services department to complete the PCA during the first week of the semester. Afterwards, the course instructor made the scores of those students who agreed to participate in this study available to the researcher. In addition, the participants completed the student background survey (see Appendix A), the SMQ-II (see Appendix C), and the Mindset Survey (see Appendix D) during the first week. Therefore, most participants in this study had the following three data sources before implementing the interventions: pre-calculus, pre-motivation, and pre-mindset.

After collecting and reviewing these scores, a purposeful sample of four students with various motivations and/or mindsets was selected from the experimental group: one participant with a fixed mindset and low motivation toward learning mathematics; a second participant with a fixed mindset and high motivation toward learning mathematics; a third participant with a growth mindset and low motivation toward learning mathematics; and a fourth participant with a growth mindset and high motivation toward learning mathematics. During the third week, a one-on-one interview with each of the case study participants was conducted (see Appendix E).

Phase II: Implementing the Interventions

For the experimental classroom, two interventions (motivation and mindset) were used. These two interventions occurred as part of regular class time and were facilitated by a fellow doctoral student in mathematics education who was neither the researcher nor the instructor. In this section, the interventions are described that follow along with a description of the qualitative data collected during this phase.

Mindset interventions. The mindset intervention was used with the experimental group during the fourth week of the Fall 2015 semester. The material for the mindset intervention included a TEDTalk (Briceno, 2012), during which the participants learned about the latest findings on malleability of the human brain. This video, which took about 10 minutes to watch, explained how hard work and good strategies on challenging tasks lead to increased intelligence in individuals. It also emphasized the advantages of strive and setbacks in providing opportunities to learn (Yeager & Walton, 2011). The video was paused at certain points, giving the participants an opportunity to share their perspective on the significant aspects of the video. The facilitator guided the participants' discussion through the use of mindset intervention prompts (see Appendix K). Then, the participants were asked to submit two writing exercises meant to reinforce the message just watched. One assignment was to use what was learned that day to give guidance to a hypothetical student who had become hopeless and started to think that she was not intelligent enough to do well in school (see Appendix J). In the second assignment (see Appendix K), the participants were asked to describe a growth and a fixed mindset in their own words and to share a personal experience related to the effect of mindset in their life. These two written assignments served as additional written reflections from case study participants on mindset interventions. After submitting their responses, the participants received their SMQ report cards along with two articles to be discussed as motivation interventions the following week. The articles and the report card will be described in the next section.

Motivation intervention. All participants in the experimental class received a report card consisting of their scores on each motivation component from the SMQ-II (i.e., intrinsic motivation, self-efficacy, self-determination, grade motivation, and career motivation) and the average scores of the class. This report served as an informative account for the participants on how their scores explained their motivation towards learning mathematics and how their scores compared to their classmates. Moreover, the report served as an indication of the areas in which participants scored low and needed interventions to improve.

Because the motivation components such as self-determination and especially self-efficacy have been found to be a strong predictor of mathematics achievement (e.g., Armstrong, 1980; Hakett & Betz, 1989; Pajares & Graham, 1999; Pajares & Schunk, 2001; Schunk, 1991; Zimmerman, 2000), the researcher targeted these motivation components in promoting participants' motivation in learning mathematics. All participants from the experimental group were provided with their motivation report cards along with interventions in the form of two articles: one promoting self-efficacy (see Appendix H) and the other self-determination (see Appendix I). A week later, the experimental group engaged in a class discussion facilitated by the same doctoral student who implemented the mindset interventions. The participants discussed the prompts, sharing their perspectives on the two mentioned articles. After 30 minutes of class discussion, each participant in the experimental group wrote two reflections (see Appendices H and I).

Qualitative data during the interventions. The four case study participants were observed before and after implementation of interventions. The participants' written reflections as well as their questions, overall interest, and reaction to motivation and mindset interventions were documented.

Phase III: Post Interventions

After implementing interventions aimed at improving the participants' mindset and motivation towards learning mathematics, students in the experimental and the control groups completed the post assessments (i.e., PCA, SMQ-II, and Mindset survey) at the end of the Fall 2015 semester. With regard to qualitative data, the last phase of this explanatory case within the intervention design was intended to use such data collected after the interventions to help explain the quantitative outcomes. To this end, after the post-tests, knowing the quantitative outcomes, the researcher created a semi-structured interview (see Appendix L) to probe deeper into the influence of interventions on the case study participants. The case study participants reflected on their experiences related to the interventions by answering questions in Appendix L. These interviews took place during the final week of the Fall 2015 semester. A schedule for procedures in this study is shown in Table 1.

Table 1

Schedule of Procedures

Procedure	Time
Collected pre-tests data from both groups using PCA, SMQ-II, mindset survey, and the student background survey	Week of August 24th (during the 1st week)
One-to-one interviews – Case study participants from experimental group	Week of September 7th (during the 3rd week)
Observational notes – Whole experimental class especially the case study participants	Before implementing interventions (as instructors' schedule permitted)
In experimental group, implemented mindset interventions, presented their motivation report cards and copies of two articles to be discussed next week	Week of September 14th (during the 4th week)
Implemented motivation interventions	Week of September 21st (during the 5th week)
Written reflections - Case participants from experimental group	Week of October 5th (during the 7th week)
Observational notes – Whole experimental class specially the case study participants	After implementing interventions (as instructors' schedule permitted)
Conducted post-test in both groups using PCA, SMQ-II, and Mindset survey	Week of November 23rd (during the last week of semester)
One-to-one interviews – Case study participants from experimental group	Week of November 23rd (during the last week of semester)

Data Analysis

Quantitative Data

The first research question in this study was: Do students in a reformed class who receive motivation and mindset interventions perform significantly better in pre-calculus achievement tests compared to students in a similar class who do not receive such interventions? To answer this question, the pre-PCA means of the groups were compared. Because the mean pre-PCA score of the experimental group was higher than the control group, an analysis of covariance (ANCOVA) with the pre-scores as a covariate was used (Field, 2013). The ANCOVA controlled for the pre-existing differences in pre-PCA scores between the groups and determined whether there was a statistically significant difference in the mean post-PCA scores in the groups.

To use this parametric test, three assumptions must be met. The first assumption is independence, which means scores from each sample have to be independent of each other. Second, the scores in each group should be normally distributed. The third assumption is the homogeneity of variance, which means the two groups must have equal variance. The samples from groups were independent from each other and had equal variance. In addition, the Shapiro-Wilk test confirmed that the distribution of scores in each group were normal.

The second research question intended to determine if students in a reformed class who receive motivation and mindset interventions show significant improvement in motivation toward mathematics compared to students in similar class who do not receive such interventions.

The experimental group scored lower than the control group before implementing the interventions in all motivation components. Therefore, the pre-existing differences were controlled for by entering the pretest scores as a covariate using an ANCOVA. The results from the ANCOVA were used to determine whether the difference in the post-motivation scores among the groups were statistically significant. The previously described assumptions were met for the data related to this research question as well.

The third research question was: Is there a difference in the proportion of students in groups with either a growth or a fixed mindset depending on condition at post-test? Does the proportion of students in the experimental group change from a fixed vs. a growth mindset from pre-to post-interventions? The dependent variable was categorical (i.e. fixed mindset, growth mindset). So using the criteria reported by Dweck and colleagues (1995), two scores were obtained from the Mindset Survey (see Appendix D): the participants' mindset toward intelligence and mathematical ability. To answer the first part of this research question, the proportion of participants in terms of mindset at post-test were compared to determine any differences among groups. To answer the second part of this research question, the change in the proportion of participants from a fixed to a growth mindset after the interventions was calculated in the experimental group.

For the three quantitative instruments used in this study (i.e., PCA, SMQ-II, and the Mindset Survey), the descriptive statistics such as mean, variance, and standard deviation for both the experimental and the control group were calculated, as appropriate.

Qualitative Data

The fourth research question, in this study was: How do individuals of different mindsets and/or motivation benefit, if at all, from the interventions? The interviews were transcribed and used to write a case record for each case study participant. All observational notes and various responses and documents pertaining to each case study were included in the participant's case record to build a comprehensive description of participants' perceptions regarding how they benefitted, if at all, from the interventions (Yin, 2014). Each case participant had a case record including the participant's holistic narrative records, which explained the impact of the interventions on that participant's motivation and mindset. Afterwards, all case records were examined to find patterns and common findings among the cases. Yin (2009) indicated that one analytic approach is to classify issues within each case and then look for common themes that transcend the cases. Moreover, besides creating within-case themes, a general explanation of the impact of interventions on participants with various motivation and mindset were used to construct a cross-case analysis (Yin, 2009). Finally, the common themes found during the within-case and cross-case analyses were used to write a holistic account for the participants receiving the interventions.

Limitations and Delimitations

Limitations

There were five limitations to this study. First, when selecting a case study participant with high motivation toward learning mathematics and a fixed mindset toward intelligence and mathematical ability, the researcher was unable to find a participant with the mentioned criteria majoring in a STEM field. Therefore, Crystal, a psychology major, was selected. Second, the results of this research may only inform similar studies in comparable universities since the unique features of the setting from which the sample was drawn may limit the generalizability of findings to dissimilar settings. Third, due to the multiple absences of a case study participant (Crystal), the researcher was unable to observe her during class time after the interventions. Fourth, collecting observational notes on all four case study participants simultaneously may have affected the entirety of the notes. Finally, as with any study that utilizes qualitative methods, the researcher was the instrument and all qualitative analysis were interpreted through the researcher's lens. Therefore, although grounded in the data, the utilization of the researcher as a study instrument was another limitation of this study (Yin, 2009).

Delimitations

The following were the delimitations in the study. First, the sample was not randomly chosen from all the pre-calculus classes that were taught traditionally; instead, the sample was selected from sections designated as reformed pre-calculus sections. Second, the selection of participants was limited to students majoring in STEM fields who were taking their first mathematics course. Third, to answer the research questions posed in the study, two non-cognitive factors were considered. As previously mentioned, the majority of studies promoting STEM education have mainly concentrated on the effects of cognitive factors, such as students' high school grade point average, SAT (the Scholastic Assessment Test), and ACT mathematics scores, as well as on students' performance in college. These two non-cognitive factors, motivation and mindset, have been found to be more significant than cognitive factors.

Chapter Summary

Chapter Three presented a mixed design methodology for this study. The mixed methods study utilized an explanatory case approach within the intervention design. Quantitative and qualitative approaches were used in collecting data to answer the four research questions. The quantitative data was gathered using four instruments: the student background survey, PCA, SMQ-II, and the Mindset Survey. Data from the case study participants were collected in the form of observational notes in the classroom, written reflections, and one-on-one interviews. Both forms of data were analyzed for providing detailed answers to the research questions in this study.

CHAPTER FOUR: RESULTS

Introduction

Educating an adequate number of graduates who are prepared for STEM careers has become one of the national priorities in the United States (Chen & Soldner, 2013). There are numerous obstacles that prevent an increase in the quantity and quality of STEM graduates. These impediments include: the shortage of qualified teachers in K-12 education; low student performance in worldwide competitions in science and mathematics; low participation of female, African American, and Hispanic students in STEM majors; lack of motivation in students; and student mindset (e.g., Beede et al., 2011; Chen & Soldner, 2013; Gonzalez & Kuenzi, 2012; Heilbronner, 2011; Hossain & Robinson, 2012; Peterson et al. 2011; Silva & White, 2013). This mixed-methods study aimed at overcoming some of the mentioned obstacles by utilizing interventions for two non-cognitive factors (i.e., the students' motivation and mindset) in a reformed pre-calculus classroom. The purpose of this study was to examine the influence of motivation and mindset interventions on students majoring in STEM fields for enhancing and improving students' success in their pre-calculus course.

In this study, both quantitative and qualitative data were gathered from students majoring in STEM in a reformed pre-calculus classroom at a public university in the southeastern region of the United States. This chapter offers the results of an analysis of the quantitative data in the form of pre- and post-tests as well as the qualitative data in the form of case studies. The following research questions were addressed:

1. Do students in a reformed class who receive motivation and mindset interventions perform significantly better on a pre-calculus achievement test compared to students in a similar class who do not receive such interventions?
2. Do students in a reformed class who receive motivation and mindset interventions show significant improvement in motivation towards mathematics compared to students in a similar class who do not receive such interventions?
3. Is there a difference in the proportion of students in groups with either a growth or a fixed mindset depending on condition at post-test? Does the proportion of students in the experimental group change from a fixed vs. a growth mindset from pre-to post-interventions?
4. How do individuals of different mindset and/or motivation benefit, if at all, from the interventions?

In the following sections of this chapter, these research questions are addressed. The first section includes the quantitative results pertaining to the first three research questions. The section contains the results from the Pre-calculus Concept Assessment (PCA), the Science Motivation Questionnaire II (SMQ-II), and the Mindset Survey. In the second section of this chapter, the fourth research question with qualitative data is addressed. These results include the analysis of each case followed by the cross-case analysis.

Quantitative Results

Pre-calculus Concept Achievement

As was explained in Chapter Three, in order to use parametric methods, the PCA scores across groups had to be normally distributed. The Shapiro-Wilk test of normality showed that the pre-PCA scores (p = .19) and post-PCA scores (p = .69) were normally distributed. Table 2 provides the descriptive statistics for the pre-PCA scores of the experimental and the control groups.

Table 2

Descriptive Statistics of Pre-PCA Scores of Participants in Both Groups

	N	M	SD
Control	23	7.70	2.65
Experimental	24	8.29	3.09

The mean pre-PCA score of the experimental group was higher than that of the control group. Therefore, to determine whether the participants in the experimental group performed significantly better on the post-PCA compared to the control group, an ANCOVA, part of the General Linear Model (GLM), with the pre-scores as covariate was used. The ANCOVA controlled for pre-existing differences in pre-PCA scores between the groups. After adjusting for the pre-score differences, the results showed that the difference between the mean post-PCA scores between groups was not statistically significant (F (1, 37) = .02, p = .89). The effect size (Cohen's d) was .06 and the observed power was .05. The post hoc power analysis revealed that in order for an effect of this size to be detected (at an 80% chance) as significant at the 5% level, a sample of 2,183 participants would be required. Figure 2 shows the comparison between the mean PCA scores of two groups before and after the interventions.

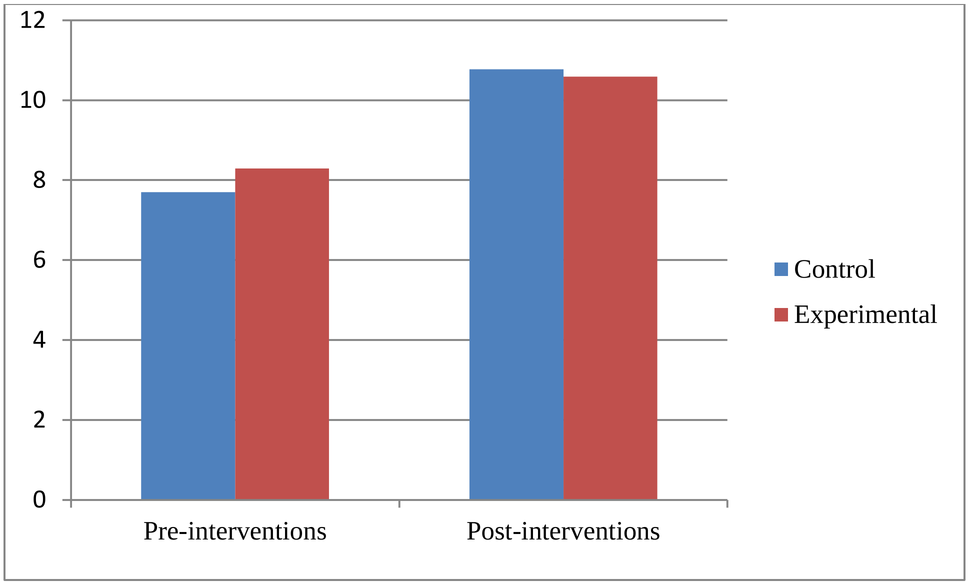

Figure 2. The average PCA scores before and after the interventions in groups.

Motivation

The assumptions of normality for the pre-SMQ scores were checked. The Shapiro-Wilk test of normality showed that the pre-total motivation scores (p = .29) and post-total motivation scores (p = .58) were normally distributed. Table 3 shows the pre-SMQ results across sections.

Table 3

A Comparison on Motivation Component Scores of Groups Before the Interventions

	Control N = 31		Experimental N = 30	
Motivation Components	Mean	SD	Mean	SD
Intrinsic motivation	12.39	3.73	10.73	3.94
Self-efficacy	15.84	2.88	15.03	3.19
Self-determination	13.55	2.85	13.40	2.93
Grade motivation	17.52	2.25	17.17	2.85
Career motivation	16.45	3.56	14.93	3.86
Total motivation	75.74	10.60	71.27	11.91

The experimental group scored lower than the control group before implementing the interventions in all motivation components. Therefore, pre-existing differences were controlled for by entering pretest scores as a covariate.

The results from the ANCOVA indicated that the differences were not statistically significant in comparing adjusted intrinsic motivation scores (F (1, 42) = 2.1, p = .15), self-efficacy (F (1, 42) = .85, p = .36), self-determination (F (1, 42) = .55, p = .46), grade motivation (F (1, 42) = .02, p = .89), career motivation (F (1, 42) = .26, p = .61), and total motivation (F (1, 42) = .27, p = .61) between groups. Table 4 provides the descriptive statistics for the adjusted post-SMQ component scores, effect size, and the observed power of the groups.

Table 4

A Comparison on Motivation Component Adjusted Scores of Groups After the Interventions

	Control N= 22		Experimental N=23			
Motivation Components	M	SD	M	SD	Effect Size (Cohen's d)	Power Obtained
Intrinsic motivation	8.78	4.78	10.51	5.05	.35	.29
Self-efficacy	12.99	3.92	13.92	3.81	.24	.15
Self-determination	13.63	3.26	12.96	3.08	.21	.11
Grade motivation	16.25	2.19	16.15	3.32	.04	.05
Career motivation	13.97	4.67	14.60	4.78	.13	.08
Total motivation	65.80	13.86	67.97	16.86	.14	.08

Results from comparison of the total motivation scores for the control and the experimental groups indicated that the control group on the average scored 4.5 points higher than the experimental group before the interventions. After controlling for pre-existing difference and using the adjusted means for comparison, the total motivation score of the experimental group on the average was 2.17 points higher than control group after the interventions. This difference was not statistically significant. Figure 3 shows this comparison.

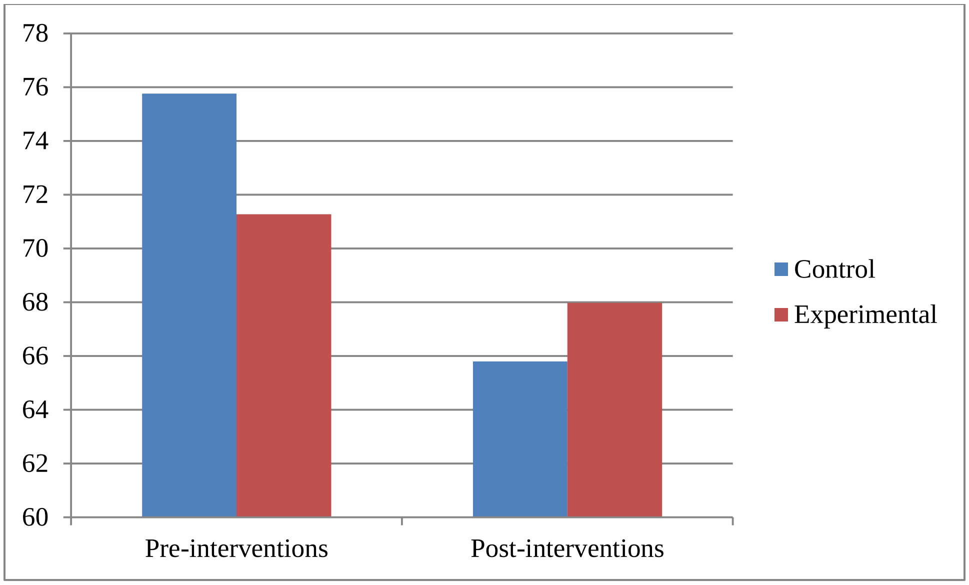

*Figure 3.*Total motivation scores before and after the interventions in groups.

Even though the experimental group scored slightly higher in almost all of the motivation components, there were no statistically significant differences between the adjusted post-SMQ scores of the groups after the interventions. Figure 4 shows this comparison.

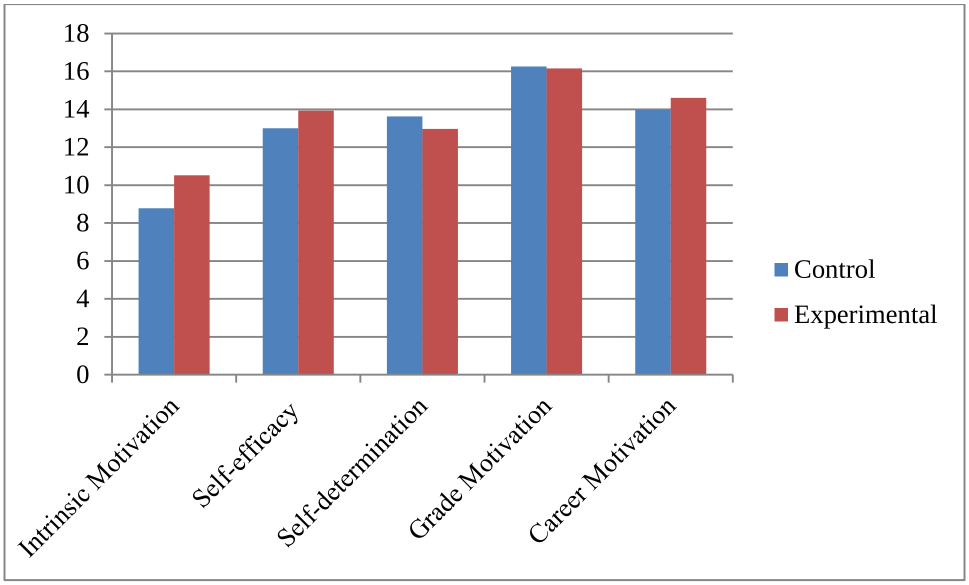

*Figure 4.*A comparison of motivation components scores in groups after the interventions.

Mindset

The criterion reported by Dweck and colleagues (1995) were used for classifying mindsets in this study. According to this classification, participants with an overall score of 3.00 or lower were identified as having a growth mindset toward intelligence/mathematical ability and as having a fixed mindset if their overall score was 4.00 or higher. The participants, who scored between 3.00 and 4.00 excluding the endpoints, were classified as “Neither.” Table 5 shows the proportion of participants’ mindset about intelligence by group.

Table 5

A Comparison of Groups' Mindset on Intelligence Before the Interventions

	Control N = 22	Experimental N = 21	
Mindset Components	Proportion	Proportion	Difference
Growth on intelligence	.82	.53	.29
Fixed on intelligence	.14	.33	.19
Neither	.04	.14	.10

The results indicated that the proportion of the participants in the control group with a growth mindset toward intelligence before the interventions was $\frac{18}{22} = .82$. However, this proportion in the experimental group was $\frac{11}{21} = .53$. The obtained results showed that the proportion of participants in the experimental group with a growth mindset toward intelligence was 29% lower than the control group before the interventions.

Table 6 shows the proportion of participants who possessed a fixed or a growth mindset on intelligence after the interventions. The result showed that the proportion of the participants in the control group with a growth mindset toward intelligence after the interventions was $\frac{17}{22} = .77$. However, this proportion in the experimental group was$\frac{17}{21} = .80$. The obtained results showed that the proportion of participants with a growth mindset toward intelligence in the experimental group was 3% higher than the control group after the interventions. Therefore, there had been a 3% difference in the proportion of participants with a growth mindset toward intelligence between groups at post-test, where the experimental group had the higher proportion. To answer the second part of research question three, the proportion of participants with a growth mindset toward intelligence increased by 27% from pre (.53) to post (.80) in the experimental group and decreased by 3% in the control condition. It should be noted that 14% and 10% were neither growth nor fixed at pre- and post-test, respectively.

Table 6

A Comparison of Groups' Mindset on Intelligence After the Interventions

	Control N = 22	Experimental N = 21	
Mindset Components	Proportion	Proportion	Difference
Growth on intelligence	.77	.80	.03
Fixed on intelligence	.18	.10	.08
Neither	.05	.10	.05

Table 7 shows the proportion of participants who possessed a fixed or a growth mindset on mathematical ability before the interventions. The proportion of the participants in the control group with a growth mindset toward mathematical ability before the interventions was $\frac{19}{22} = .86$. Similarly, this proportion in the experimental group was $\frac{18}{21} = .86$. The obtained results showed that the proportion of participants with a growth mindset toward mathematical ability was the same in the groups before the interventions.

Table 7

A Comparison of Groups' Mindset on Mathematical Ability Before the Interventions

	Control N = 22	Experimental N = 21	
Mindset Components	Proportion	Proportion	Difference
Growth on intelligence	.86	.86	.00
Fixed on intelligence	.04	.10	.06
Neither	.10	.04	.06

Table 8 shows the proportion of participants who possessed a fixed or a growth mindset toward mathematical ability after the interventions. The proportion of the participants in the control group with a growth mindset toward mathematical ability after the interventions was $\frac{18}{22} = .80$. However, this proportion in the experimental group was $\frac{19}{21} = .90$. The results showed that the proportion of participants with a growth mindset toward mathematical ability in the experimental group was 10% higher than the control group after the interventions. Therefore, there had been a 10% difference in the proportion of participants with a growth mindset toward mathematical ability between groups at post-test, where the experimental group had the higher proportion. To answer the second part of research question three, the proportion of participants with a growth mindset toward mathematical ability increased by 4% from pre (.86) to post (.90) in the experimental group.

Table 8

A Comparison of Groups' Mindset on Mathematical Ability After the Interventions

	Control N = 22	Experimental N = 21	
Mindset Components	Proportion	Proportion	Difference
Growth on intelligence	.80	.90	.10
Fixed on intelligence	.10	.05	.05
Neither	.10	.05	.05

In the following paragraphs results from the Mindset Survey are summarized. The post-proportions in the control group with a growth mindset on intelligence decreased by 5% from their respective pre-proportion, and the proportion of participants with a fixed mindset toward intelligence increased by 4% (from .14 to .18). In the experimental group, the post-proportion of the participants with a growth mindset on intelligence increased by 27% from their respective pre-proportion. This caused a decrease in the proportion of participants with a fixed mindset toward intelligence in the experimental group, by 23% (from .33 to .10).

Moreover, the percentage of participants in the control group who indicated that mathematical ability was inborn and could not be improved with instruction and hard work (a fixed mindset) increased by 6% (from .04 to .10), decreasing the proportion of participants with a growth mindset by 6% reaching .80 (from .86 to .80). In the experimental group, participants showed a decrease in having a fixed mindset toward mathematical ability by 5% (from .10 to .05), increasing the proportion of participants with a growth mindset by 4% (from .86 to .90). Figure 5 illustrates the proportion of the groups' growth mindset before and after the interventions.

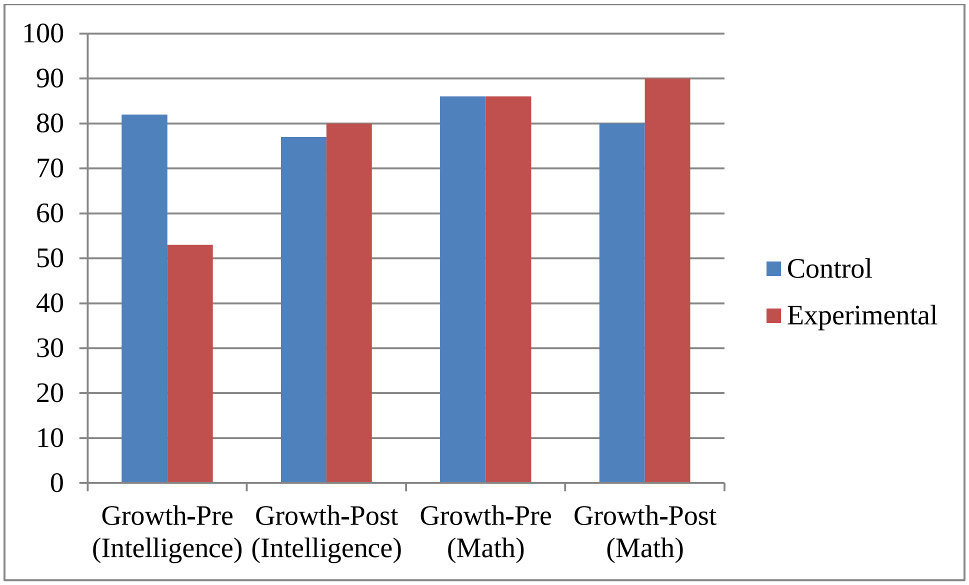

Figure 5. A comparison of groups' growth mindset on intelligence and mathematical ability before and after the interventions.

Summary of Quantitative Results

To answer the first three research questions in this study, three instruments (i.e., PCA, SMQ-II and the Mindset Survey) were used. The analysis of the results from PCA and SMQ-II scores in groups showed no statistically significant difference at post-tests after controlling for the pre-existing differences in pre-test scores. When comparing the two groups at post-tests, there was a difference in the proportion of participants with a growth mindset toward intelligence (3%) and mathematical ability (10%), where the experimental group had the higher proportions. There was an increase in the proportion of participants in the experimental group with a growth mindset toward intelligence (27%) and mathematical ability (4%) from pre to post.

Qualitative Results

In this section, qualitative results are presented to answer the fourth research question: How do individuals of different mindset and/or motivation benefit, if at all, from the interventions? A purposeful sample of four participants from the experimental group was selected based on the participants' total-SMQ-II motivation score and mindset toward intelligence and mathematical ability. Table 9 displays the four case study participants along with their classifications for motivation and mindset based on the surveys taken at the onset of the study.

Table 9

The Case Study Participants' Motivation and Mindset

Pseudonym	Motivation Score for Learning Mathematics	Mindset toward	
		Intelligence	Mathematical Ability
Adele	Low	Fixed	Fixed
Daniel	Low	Growth	Growth
Crystal	High	Fixed	Growth
Marge	High	Growth	Growth

In the following sections, four individual case study narratives are presented. In each case, the information obtained from the student background survey, the pre- and post-total motivation scores, the pre- and post-mindset surveys toward intelligence and mathematical ability, the pre- and post-interviews, the pre- and post-observational notes, and written reflections are described. To build a comprehensive perception into how participants of different motivation scores and/or mindsets benefited, if at all, from the interventions, all observational notes and various responses and documents related to each case study are included in the participant's case record. The presentation of the four cases is followed by a cross-case analysis.

Adele's Case

Student background survey. Adele was a 20-year-old, white female majoring in biology. Her high school GPA was 3.8 and her score on the ACT was 20. This was her first time taking the pre-calculus course. She liked group work in mathematics classes and preferred face-to-face instruction over online teaching (Student Background Survey, 8/24/2015). Adele had a low motivation toward learning mathematics and a fixed mindset toward intelligence and mathematical ability.

Pre-intervention interview. Adele participated in a one-on-one interview before implementing the interventions. The prompts for this interview are included in Appendix F. When asked to compare a traditional mathematics classroom with a reformed-oriented one, indicating the advantages and disadvantage of each, she replied:

> I think an advantage to the group reform-oriented one is if you don't understand something, someone else in your group might understand and they can help you and explain it. A disadvantage to that, though, is that it kind of makes me feel like I don't have to do as much because someone else in my group will do some of it, too. I don't work as hard with that as if I am doing it individually. (Pre-interventions Interview, 9/7/2015)

Adele stated that in a reformed classroom, since students work in groups, if an individual did not understand something, someone else in the group could help by explaining it to the group. A disadvantage of a reformed classroom, in her opinion, was that she would not feel as responsible for the assigned homework compared to if she was working individually, since others in the group were working on the same tasks.

When Adele was asked, “How important is the role of mathematics in our lives?” she responded by saying:

> I think, obviously, we use it all the time; maybe not as in depth like complicated math but we use simple math for everything in our daily lives. We use simple addition and subtraction for everything like we measure things. We use simple math all the time, not as much complex math, although some people do. (Pre-interventions Interview, 9/7/2015)

Adele indicated that mathematics played an important role in our lives because it was used all the time, from simple addition, subtraction, and measuring things, to complex mathematics.

Then, she was asked to disclose the most interesting topic in pre-calculus so far. She replied:

> The thing I like most about pre-calculus is that a lot of the problems are word problems and they use real-life examples; like this person and this person are walking toward each other. I think that helps me because I can visualize it more. When we are just using letters and stuff it doesn’t have a real visual meaning. (Pre-interventions Interview, 9/7/2015)

After two weeks of instruction, Adele indicated that one of the most interesting things in pre-calculus class so far had been using the real-life examples in the word problems. She liked the word problems because she could visualize them, like the problem of two people walking toward each other. She disliked mathematics problems presented in mathematical notations only.

When Adele was asked, “What motivates you to learn mathematics and why?” she responded:

> Well, I think my grades, obviously, motivate me a lot because I need to keep my GPA up. I will have to use math in my job so, I need to learn it, too, instead of just getting through it. Future jobs motivate me the most but grades, as well. (Pre-interventions Interview, 9/7/2015)

The reason for her motivation to learn mathematics was earning good grades and a high GPA. Her second motivation to learn mathematics was her future career in biology, since Adele knew she needed to learn mathematics instead of just trying to pass the course.

She was then asked, “If you were to fail your first exam in pre-calculus, what strategies would you use to improve your grades?” Adele answered:

> I would probably go to a tutor and try to bring some of the work we do, like in our workbook. I know they aren’t supposed to work with us on the graded stuff. I would have them explain it to me. I could also go to the teacher and ask her if she had any advice on studying and practicing. The big help in math is just doing it over and over. I think that’s it. (Pre-intervention Interview, 9/7/15)

If she failed the first exam in this class, Adele’s strategy to improve her grades was to go to a tutor or the teacher. Adele indicated that she would seek the teacher’s help and advice on studying and practicing.

Observational notes before the interventions. The experimental classroom observation took place during the third week of the semester at the class’s regular instruction time from 11:30 a.m. to 12:25 p.m. As participants entered the classroom, they noticed their name in one of the seven groups showing on the overhead projector. Every group consisted of four to five participants sitting around a circular table. The researcher chose to sit in the back of the classroom where she could see and hear all of the groups.

The instructor went around to the tables, asking the students whether they had any questions or concerns regarding the previous lessons. Then, she made the following announcement to the whole class:

> Last week we talked about linear functions and how we use them in our daily lives. Today we want to write a linear function modeling a real-life situation. Look at the problem now showing on the overhead projector and think about it in your group.

The problem was as follows: Tim works 30 hours a week between two part-time jobs: waiter ($9.25 per hour) and math tutor ($8.50 per hour). Since he has only 30 hours each week that he can work, the more hours he spends at one job the fewer hours remain for the second job. Assume that Tim worked a total of 30 hours this week and he worked 9 hours as a waiter. How much money in total did Tim make this week? Explain how you determined your answer.

The participants started thinking and then talking amongst themselves to solve the problem. Adele’s group consisted of a male participant, a female participant, a case study participant named Crystal, and Adele. The male participant in the group asked Adele how she would solve the problem. She answered, “I have no idea!” Crystal and the other female participant in the group jotted down things on their papers trying to model the situation with a linear function.

Adele did not appear interested in trying to solve the assigned problem. She did not appear to pay any attention to her classmates' collaboration for solving the problem and looked extremely confused and anxious. On the day of the observation, she used a language suggestive of a fixed mindset: "I have no idea!"

Mindset interventions. During the mindset interventions, Adele responded to the following three prompts: initial prompt, final prompt, and written assignment.

The prompt for the initial response was, "Think about this question and reply in initial writing response part: Is your intelligence fixed (you cannot change it), or can it be improved?" Adele responded:

> I think some people have a better ability to learn certain things. Some people are more intelligent than others in math or English, etc. I think you can improve your intelligence. You can build on the knowledge you already have if you have the determination to improve yourself. I don't necessarily think it's fixed. (Mindset Interventions, 9/14/2015)

She stated that ability to learn certain subjects such as mathematics or English was different for everyone, suggesting some have an easier time learning the subject than others. She also indicated that intelligence could be improved if the person was determined to do so. Adele's mindset that some people could perform better than others in specific areas such as mathematics or English signified her fixed mindset toward intelligence.

At the end of the mindset interventions, the experimental group was asked to reply to the following statement as the final response: “Think about this question and reply in final writing response part: In your own words, describe a growth and fixed mindset and share your personal experience related to the effect of mindset in your life.” Adele responded with the following:

> A growth mindset means you think you can learn more so you try harder to improve your knowledge level. A fixed mindset means you tell yourself you can’t do it and you give up. If something doesn’t come easily to you, you won’t keep trying. I have experienced both kinds of mindsets before. I got a bad grade on a test in chemistry on the very first test so I told myself I can’t do chemistry and gave up. I didn’t study anymore and I continued to get bad grades. (Mindset Interventions, 9/14/2015)

Adele’s final response indicated that she had experienced both mindsets (fixed and growth) in her life. However, in the initial mindset response, she indicated that some subjects were not easily learned by some; and here she disclosed that when chemistry was hard for her she did not keep trying and gave up. Her responses were mostly aligned with having a fixed mindset toward intelligence and learning mathematics.

The experimental group completed the last written assignment by utilizing what they learned that day to give a hopeless student (Vanessa) advice (see Appendix J). Adele’s advice to Vanessa was:

> She should take that bad grade and use it as motivation. She should get a tutor and study it harder. If she did good in high school she can do good again. It was just one test and the whole grade isn’t based on one test. She can realize she needs to

> work harder and it's not high school anymore. She can't base her whole life goal off of one bad test grade. She needs to shake it off and use it as a tool to improve herself. Everybody does badly sometimes. (Mindset Interventions, 9/14/2015)

Adele gave Vanessa, the hopeless student, advice promoting a growth mindset in her. She advised Vanessa to use this setback as a motivation tool and to increase her efforts in studying harder, which could lead to grade improvement. Evidently, her failing experience in chemistry class had taught her the value of persistence and continued effort to reach success. She was sharing this growth mindset message with Vanessa.

On the last week of Fall 2015, the results from post-mindset survey signified that Adele's belief regarding mindset on intelligence and learning mathematics had changed from a fixed mindset on both to a growth mindset on both.

Motivation interventions. The experimental group participated in the motivation interventions (see Appendices H and I). These interventions were implemented one week after the mindset interventions (9/21/2015). One of the assignments was to reflect on the following statement: "In your own words, explain how you can improve your self-efficacy in learning mathematics. From the four ways discussed to improve self-efficacy, which one has been the most effective for you?" The following was Adele's response:

> I think you can improve your math skills by practicing a lot. You should start off with more simple problems then eventually get to the harder questions. I also think that watching people do the work at first is very helpful. I think peer modeling is the most useful of the four ways to improve self-efficacy. After you have started figuring out how to do something you feel more confident and your quality of work will improve as well. (Motivation Interventions, 9/21/2015)

Adele indicated that her self-efficacy in learning mathematics would improve by practicing on more problems, starting with simpler ones. From the four sources to improve self-efficacy (i.e., enactive mastery, vicarious experiences, verbal persuasion, and physiological reaction), she preferred the vicarious experiences (i.e., watching others performing the task) to be the most helpful. Adele had now realized that to be successful in mathematics, she needed to practice, collaborate, and watch others perform mathematics. Her motivation toward learning mathematics appeared to contrast with her pre-intervention behavior, since during the observation day before the interventions she did not seem interested in collaborating or watching her classmates in solving the assigned problem.

The second assignment for motivation interventions was to reflect on the following statement: “Think about this question and reply in time management response part: In your own words, explain how you can improve your time management. From the 10 strategies suggested in the article (see Appendix I) to improve time management, which one has been the most effective for you?” Adele’s response follows:

> I can improve my time management by actually writing everything down in my planner and not just the big things. I think writing down even the little tasks would be helpful. Also not procrastinating is the biggest one. I would do so much better in school on tests and homework if I started on them as soon as they were assigned. Then I would actually have more relaxing time if I knew all my work was already done. (Motivation Interventions, 9/21/2015)

To improve her time management, Adele considered writing all her tasks in a planner to allocate the appropriate time to them. From the 10 strategies discussed in the article, she indicated “to stop procrastinating” to be the most effective way of time management. Adele appeared to realize how she could benefit from using the time management tips in studying and doing her homework promptly.

Adele’s pre-total motivation score was 59, about one standard deviation below the experimental class’s mean (*M* = 71.27, *SD* = 11.91). Even though on average, the post-total motivation scores in the experimental group declined from their respected pre-scores (*M* = 66.74, *SD* = 16.86), Adele’s post-total motivation score stayed the same (59).

Written reflection. Two weeks after the experimental group’s participation in the interventions, the case study participants were asked to reflect on their recent experience by responding to the questions in Appendix L. In this section, Adele’s responses are presented.

In response to the question on whether her motivation toward learning mathematics had changed any, she replied, “I have started believing in myself more and realized if I try hard enough, I can push myself through any problem. I can be successful in math even though I don’t enjoy it” (Written Reflection, 10/5/2015). The change that she believed had happened regarding her motivation toward learning mathematics was that she had started to believe in herself and had realized that she could overcome any obstacle if she tried hard. This reflection provided evidence to suggest that as a result of the interventions, Adele’s mindset had changed promoting a growth mindset toward learning.

When asked, “How have the motivation interventions promoted your interest in learning mathematics?” she replied, “I’m still not really interested in math but I do think I’ve realized that I can do it if I put my mind to it” (Written Reflection, 10/5/2015). Her lack of interest in learning mathematics had not changed but because of the motivation interventions, she had realized that she would be successful in learning mathematics if she wanted to. Her response to this question had also demonstrated a growth mindset toward learning.

When asked about the lesson that she learned during the mindset interventions that surprised her, she replied: “That you actually change the amount of intelligence you have. I didn’t realize mindset really made that much of a difference on how you learn” (Written Reflection, 10/5/2015). She learned two lessons from mindset interventions, which surprised her. One was the fact that an individual’s intelligence could be changed. The second lesson that she learned was the effect of a mindset on how one learns. Clearly, she had been surprised to learn the two important messages of a growth mindset indicated above.

Adele was asked about the impact of an individual’s mindset about intelligence on his/her learning. She responded:

> I think if you have the mindset that you can be successful in whatever you do, you’ll be more likely to succeed. If you think you’re intelligent you’ll go further with it because you have confidence and believe in yourself. (Written Reflection, 10/5/2015)

She stated that one’s mindset had a direct effect on learning. She explained that an individual would work harder to achieve success if he was confident and believed that he could accomplish victory in whatever he did.

When asked about how her experience during interventions had changed her perception toward learning in general, she replied:

> It made me realize you can change the way you learn about things. You can be more successful when you believe in yourself. If you think you can do something you'll push yourself harder, and in return learn more. (Written Reflection, 10/5/2015)

Adele acknowledged that her perception of successful learning in general was to believe in one's abilities and pushing harder to learn more. This response was another indication to suggest that her mindset toward learning in general had changed from thinking some people performed better in certain subjects to believing in one's capabilities and persistence in generating success.

Observational notes after the interventions. During the eighth week of instruction, the observational notes were collected by observing the experimental group, with particular attention to the case study participants. The observation occurred during instruction time from 11:30 a.m. to 12:25 p.m. The participants came to the classroom and looked for their assigned group, which was projected by overhead on the whiteboard. The instructor went around to the tables asking students whether they had any questions or concerns regarding previous lessons. Then she made the following announcement to the whole class:

> Last time we started a new chapter talking about Trigonometric Functions. We talked about the two mostly used measurements for an angle, radians and degrees, and how they are related. Let's look at this problem: April is riding on a circular Ferris wheel that has a radius of 51 feet. After boarding the Ferris wheel, she traveled a distance of 32.2 feet along an arc before the Ferris wheel stopped for the next rider.

a) Make a drawing of the situation and illustrate the relevant quantities.

b) The angle that April swept along the arc had a measure of

i) how many radians?

ii) how many degrees?

Adele and her group chuckled as they tried to draw the Ferris wheel, with the appropriate radius and the arc that April traveled. Adele drew the Ferris wheel marking the radius and the arc with their measurements in feet as was the problem's requirements. Then she asked the group for any suggestions to solve the second part. One of the female participants in the group said that she had seen two formulas in the textbook the night before. The group collaborated in solving the second part of the problem using those formulas.

Adele did not use a language suggestive of a growth or fixed mindset on the day of observation, unlike her usage of a fixed mindset language on pre-observation day. Her behavior indicated that she was interested in trying to solve the assigned problem. She collaborated and discussed the problem with her group.

Post-intervention interview. During the last week of instruction, the last interview was conducted with the case study participants. The prompts for this interview are included in Appendix G. Adele's responses follow.

When asked, "Have the interventions enhanced your motivation and mindset toward mathematics? If so, in what way? If not, why not?" she replied:

> I think it has because, when we were watching the video, it really made me think that you could change and having a different mindset toward math really could help you learn it more. With the reading and everything, it had tips on time

> management, that I think could help you get better at math. (Post-interventions Interview, 11/23/2015)

Adele recognized that the interventions had enhanced her learning because they caused her to consider having a different mindset (i.e., a growth mindset) toward mathematical ability. She benefited from the time management tips discussed during the motivation interventions.

The second question in this interview was: “How do you think this experience can influence other aspects of your life, if at all?” She responded:

> The time management can help you with everything. If you spend your time well, you can design any subject that you are studying for. Even at home, if you spend some time doing this or some time doing that, you can get more things done. (Post-interventions Interview, 11/23/2015)

She indicated that the 10 strategies for time management discussed during the interventions had been helpful in managing her time wisely and had created extra time to get more things done at home and school.

In response to the prompt, “What was the most interesting part of the interventions, if any? Explain why it was so interesting to you,” Adele replied, “I thought the video talk was interesting because it opened my eyes to see that you really can get yourself through things if you just believe in yourself. You can push through anything” (Post-interventions Interview, 11/23/2015). The TEDTalk video (Briceno, 2012) was the most interesting part of the intervention for Adele because it made her realize that she could overcome anything with effort and hard work. She appeared to have benefited from learning the message expressed in the video talk during the mindset interventions.

When asked, “How has your attitude toward learning a new skill or craft changed, if at all? If so, why? If not, why not?” she responded:

> I think it has made me have a better attitude towards it. I realize if you believe that you can do it, you tell yourself you can do it, you spend more time studying and practicing it, you actually do see a better outcome. It has just made me believe in myself more, especially with math. Before, I just thought I wasn’t good at it and so I didn’t really try that much, but the reading and the videos have kind of made me see that I can get through it. (Post-interventions Interview, 11/23/2015)

Adele’s mindset toward learning a new skill after the interventions had changed. She indicated that before interventions, she would not attempt learning something if she thought she was not good at it. Adele had now realized that if she believed in herself, studied, and practiced more, she would achieve a better outcome.

The last questions in this interview were, “What was the most important lesson that you learned from the interventions? How can it influence your future?” She replied:

> I think it can influence your future in math, especially, like I said before, I wasn’t really thinking that I was that good at math, so I wasn’t going to try that hard but just put it to the side. Now, I think that I can just study more whereas before, I didn’t really think you needed to study for math. I believed you either get it or you don’t. Now, I know that I can study for things; I can learn them and I can see an improvement in myself. (Post-interventions Interview, 11/23/2015)

Adele reflected on some of the important lessons that she had learned from the interventions. She learned that her belief toward learning mathematics was aligned with having a fixed mindset and that had kept her from studying harder. Adele realized that in order to be successful in math, she needed to study and practice for mathematics like any other subjects.

Adele's overall summary. In this section, qualitative data drawn from Adele's case regarding the fourth research question were highlighted. The evidence in this overall summary is meant to support how Adele benefitted, if at all, from the interventions.

Adele, who began the study with low motivation toward learning mathematics, and a fixed mindset toward intelligence and mathematical ability, benefited in six ways from the interventions. First, she stated that the motivation interventions made her realize that to improve her mathematics skills she needed to study mathematics like any other subject. Her belief regarding learning mathematics changed from thinking "either you get it or you don't" (Post-interventions Interview, 11/23/2015) to "practice over and over" (Post-interventions Interview, 11/23/2015). Second, Adele indicated that the best way for her to improve her mathematics skills was to start by solving simpler problems and learn from watching others solve problems (Motivation Interventions, 9/21/2015). Third, she also stated that time management strategies discussed during motivation interventions could be extremely helpful in improving her success in all aspects of her life (Motivation Interventions, 9/21/2015). Fourth, Adele stated that the mindset interventions were beneficial for changing her mindset toward learning in general. She explained, for example, how her fixed mindset in giving up and not studying had caused her to get more bad grades when failing a test in chemistry (Mindset Interventions, 9/14/2015). Fifth, after experiencing the mindset interventions, she realized that by spending more time studying, practicing, and believing that she could achieve success, she would experience success (Post-interventions Interview, 11/23/2015). Sixth, she indicated that the mindset interventions had made her believe in herself more, especially with learning mathematics (Post-interventions Interview, 11/23/2015).

The above evidence confirmed that Adele had benefited from the interventions. Her motivation score after the interventions did not decrease and stayed the same unlike the trend in her group. Her mindset score toward intelligence and mathematical ability changed from a fixed mindset on both before the interventions to a growth mindset on both after the interventions. Adele's writing samples and interviews provided evidence of her understanding in the role that mindset plays in learning and achievement. She acknowledged that the interventions were the primary reason that promoted her change in mindset toward intelligence and mathematical ability.

Daniel's Case

Student background survey. Daniel was a 22-year-old, African American male, majoring in biology. His high school GPA was 3.2 and his score on the ACT was 19. This was his first time taking the pre-calculus course. He did not like group work in mathematics classes and preferred online teaching over face-to-face instruction (Student Background Survey, 8/24/2015). Daniel had a low motivation toward learning mathematics, and a growth mindset toward intelligence and mathematical ability.

Pre-intervention interview. Daniel participated in a one-on-one interview before implementing the interventions. The prompts for this interview are included in Appendix F. When asked to compare a traditional mathematics classroom to a reformed-oriented class, indicating advantages and disadvantage of each, he replied:

> Personally, I think I prefer lecture in class instead of doing it alone. That is because, if lecture is in class, then you learn it there and you can ask questions

> there instead of waiting and having to do the work and then trying to ask questions. I prefer it like that. I guess, reformed, it will actually give you a chance to work it out on your own and see if you can do it before asking the questions. I guess that creates independence. I guess both of them work in different ways. (Pre-interventions Interview, 9/7/2015)

He compared a traditional classroom with a reformed-oriented one, indicating his preference for the traditional classroom. The advantage that he mentioned for his choice was that, in a traditional classroom when the teacher gave a lecture, students could learn the material and ask questions right after the lecture. The advantage that he pointed out for a reformed classroom was that it created independent students by giving them a chance to work out the problems on their own before asking questions.

When Daniel was asked, “How important is the role of mathematics in our lives?” he responded by saying:

> I feel like it varies, depending on what your job is. Some people may use little math, daily, and others have to do calculations, probably, throughout their whole day. I think it just varies but it plays a big role, depending on the individual. For example, my major is biology but I plan to work on animals so, I am not really going to use too much pre-calculus or calculus. (Pre-interventions Interview, 9/7/2015)

Daniel stated that even though mathematics played an important role in our lives, the importance varied with how much mathematics an individual was required to use on his job. He indicated that since his major was biology, he did not need higher-level mathematics courses such as pre-calculus and calculus. Daniel appeared to justify his lack of motivation toward learning mathematics by stating that higher level mathematics is not needed in his future career as a biologist.

Then, he was asked about the most interesting topic in pre-calculus so far for him. He replied, “For my major, I haven’t really noticed anything too interesting. It might be interesting for someone of another major but, for right now, I haven’t really noticed anything that speaks to my interest, really” (Pre-interventions Interview, 9/7/2015). After two weeks of instruction, Daniel had not noticed any interesting topic in pre-calculus related to his major.

When Daniel was asked, “What motivates you to learn mathematics and why?” he responded, “Just so that if anything, daily, comes up, I am able to handle it and conquer it or whatever” (Pre-interventions Interview, 9/7/2015). Daniel’s motivation to learn mathematics was to be able to fulfill the essential, daily need of using mathematics.

He was then asked, “If you were to fail your first exam in pre-calculus, what strategies would you use to improve your grades?” Daniel answered, “I would look at the way I studied before and go back and adjust it. Maybe I would use flash cards for the next time or just different tools that could be used” (Pre-intervention Interview, 9/7/15). His strategy to improve his grade if he failed the first exam was to reflect on the way he studied for that exam. He would use flash cards or different tools adjusting the way he studied. His response to this question indicated his growth mindset; when faced with a failure, he would try using different strategies to accomplish success.

Observational notes before the interventions. The experimental classroom observation took place during the third week of the semester at the class’s regular instruction time from 11:30 a.m. to 12:25 p.m. As participants entered the classroom, they noticed their name in one of the seven groups showing on the overhead projector. Every group consisted of four to five participants sitting around a circular table. The researcher chose to sit in back of the classroom where she could see and hear all of the groups.

The instructor went around to the tables asking students whether they had any questions or concerns regarding the previous lessons. Then, she made the following announcement to the whole class:

> Last week we talked about linear functions and how we use them in our daily lives. Today we want to write a linear function to model a real-life situation. Look at the problem now showing on the overhead projector and think about it in your group.

The problem was as follows: Tim works 30 hours a week between two part-time jobs; waiter ($9.25 per hour) and math tutor ($8.50 per hour). Since he has only 30 hours each week that he can work, the more hours he spends at one job the fewer hours remain for the second job. Assume that Tim worked a total of 30 hours this week and he worked 9 hours as a waiter. How much money in total did Tim make this week? Explain how you determined your answer.

The participants started thinking and then talking amongst themselves to solve the problem. Daniel’s group consisted of two female participants, a male participant, and Daniel. Daniel did not collaborate or reach out to his group members for help solving this problem; he quietly worked on the problem on his own. After a few minutes, one of the female participants came up with the solution and shared it with the rest of the group.

In his student background survey, Daniel indicated that he did not like group work. On the day of observation he did not appear interested in collaborating to solve the problem with his classmates. Even though he was not able to solve the problem on his own, he did not ask his classmates for help. Daniel did not use any language suggestive of a growth or fixed mindset on the day of observation.

Mindset interventions. During the mindset interventions, Daniel responded to the writing prompts. The prompt for the initial response was, "Think about this question and reply in initial writing response part: Is your intelligence fixed (you cannot change it), or can it be improved?" Daniel responded, "I believe all things can be improved through hard work and a willingness to succeed. I just believe that everyone learns in different ways so the teaching needs to be adaptable to each student" (Mindset Interventions, 9/14/2015). He stated that teaching needed to be personalized for every student since every individual learned in different ways. Daniel also indicated that everything, including intelligence, could be improved through effort and motivation to be successful. His response to this question provided additional evidence that he had a growth mindset toward intelligence.

At the end of the mindset interventions, the experimental group was asked to reply to the following statement as the final response: "Think about this question and reply in final writing response part: In your own words, describe a growth and fixed mindset and share your personal experience related to the effect of mindset in your life." Daniel responded with the following:

> Growth mindset is the willingness to improve. Fixed mindset is being content with your limits. Fixed mindset comes into play personally with math. I know I

> won't use it in my career so it just annoys me to do it past the basic essentials. (Mindset Interventions, 9/14/2015)

Daniel described a growth and a fixed mindset accurately. Although he claimed to have a fixed mindset toward mathematical ability, he was referring to his lack of motivation toward learning mathematics. He explained that his reason for having a low motivation to learn mathematics was the lack of demand in using higher level mathematics in his future career.

The experimental group completed the last written assignment by utilizing what they learned that day to give a hopeless student (Vanessa) advice (see Appendix J). Daniel's advice to Vanessa was:

> I would tell her that God got her this far and isn't going to let her down. I'll tell her to keep her head up and faith strong. Add a little more effort and the Lord will see her through to the end. (Mindset Interventions, 9/14/2015)

He gave Vanessa, the hopeless student, spiritual advice. He advised her to increase her efforts and to keep her faith to God strong so that she would be successful. His advice of working harder and to continue the efforts until success was conveying the growth mindset message to her.

On the last week of Fall 2015, the results from post-mindset survey signified that Daniel's belief in a growth mindset regarding intelligence and mathematical ability had not changed since the pre-mindset survey.

Motivation interventions. The experimental group participated in the motivation interventions (see Appendices H and I). These interventions were implemented one week after the mindset interventions (9/21/2015). One of the assignments was to reflect on the following statement: “In your own words, explain how you can improve your self-efficacy in learning mathematics. From the four ways discussed to improve self-efficacy, which one has been the most effective for you?” The following was Daniel’s response: “Self-motivation and practicing learned skills. Personally physiological reaction has been the most helpful to me” (Motivation Interventions, 9/21/2015). Daniel stated that his self-efficacy in learning mathematics would improve by self-motivation and through applying what he had learned before. From the four sources to improve self-efficacy (i.e., enactive mastery, vicarious experiences, verbal persuasion, and physiological reaction), he picked the physiological reaction (i.e., to perceive emotional states with optimism or a positive mood) as the most helpful source. Daniel, with low motivation toward learning mathematics, had indicated that self-motivation, practicing learned skills, and physiological reaction would improve his self-efficacy in learning mathematics. His strategies to promote self-efficacy and ultimately motivation in learning mathematics seemed ineffective.

The second assignment for motivation interventions was to reflect on the following statement: “Think about this question and reply in time management response part: In your own words, explain how you can improve your time management. From the 10 strategies suggested in the article (see Appendix I) to improve time management, which one has been the most effective for you?” Daniel’s response was, “Set priorities are the biggest time management tool for me. Deciding what is important or can be saved for later while I focus on more urgent matters” (Motivation Interventions, 9/21/2015). Daniel stated that in order to improve his time management, he needed to know how to prioritize his tasks, recognizing the distinction between what was important and what was urgent. From the 10 strategies discussed in the article, Daniel indicated that “to set priorities” was the most effective way of time management.

Daniel’s pre-total motivation score was 51, about one standard deviation below the experimental class’s mean (*M* = 71.27, *SD* = 11.91). The post-total motivation average scores in experimental group declined compared to their respected pre-scores (*M* = 66.74, *SD* = 16.86). Daniel’s post-total motivation score was 28.

Written reflection. Two weeks after the experimental group’s participation in the interventions, the case study participants were asked to reflect on their recent experience by responding to the questions in Appendix L. In this section, Daniel’s responses are presented.

In response to the question regarding whether his motivation toward learning mathematics had changed any, he replied, “Unfortunately, I still do not have the motivation to seek out and eagerly learn mathematics” (Written Reflection, 10/5/2015). He stated that his low motivation to learn mathematics had not changed since the beginning of the course.

When asked, “How have the motivation interventions promoted your interest in learning mathematics?” he replied, “I used the interventions for help in other aspects of my life, but not so much with my interest in mathematics” (Written Reflection, 10/5/2015). Daniel did not use the motivation interventions to promote his interest in learning mathematics. However, these interventions were helpful in advancing other aspects of his life.

When asked about the lesson that he learned during the mindset interventions that surprised him, he replied, “The number of techniques that can be used to change a person's mindset towards a subject" (Written Reflection, 10/5/2015). Daniel learned that there were many ways that a person's mindset toward a subject could be changed.

He was asked about the impact of an individual's mindset about intelligence on his/her learning. He responded, "It positively or negatively affects their efforts towards learning and directly affects the output" (Written Reflection, 10/5/2015). Daniel indicated that an individual's effort toward learning and its output were directly influenced by the person's mindset (i.e., a growth mindset has a positive effect toward learning and its output and a fixed mindset has a negative effect toward learning and its output).

When asked about how his experience during interventions had changed his perception toward learning in general, he replied, "It has opened my eyes to just how powerful believing in yourself can be. The amount someone can accomplish just by saying they can do something or won't stop until they can" (Written Reflection, 10/5/2015). Daniel acknowledged that his perception of successful learning in general was to believe in one's abilities and not to give up until the task was successfully completed. His response to this question had shown how effective the interventions were in reinforcing his growth mindset toward learning in general.

Observational notes after the interventions. During the eighth week of instruction, the observational notes were collected by observing the experimental group in general and the case study participants in particular. This observation occurred during instruction time from 11:30 a.m. to 12:25 p.m. The participants came to the classroom and looked for their assigned group, which was projected on the whiteboard. The instructor went around to the tables, asking students whether they had any questions or concerns regarding previous lessons. Then, she made the following announcement to the whole class:

> Last time we started a new chapter talking about Trigonometric Functions. We talked about the two mostly used measurements for an angle, radians, and degrees, and how they are related. Let's look at this problem: April is riding on a circular Ferris wheel that has a radius of 51 feet. After boarding the Ferris wheel, she traveled a distance of 32.2 feet along an arc before the Ferris wheel stopped for the next rider.
>
> a) Make a drawing of the situation and illustrate the relevant quantities.
>
> b) The angle that April swept along the arc had a measure of
>
> i) how many radians?
>
> ii) how many degrees?

Daniel's group consisted of one male participant, two female participants, and Daniel. They all tried to draw the Ferris wheel with the related radius and the arc that April had traveled. Then, the conversation in the group shifted to amusement parks momentarily. The male student (who was not Daniel) pointed out the formulas to be used for solving the second part of the assigned problem.

Although Daniel appeared interested in solving the assigned problem with his classmates, he was still hesitant to contribute to his classmates' conversation and showed preference to work alone. Daniel did not use a language suggestive of a growth or fixed mindset on the day of observation.

Post-intervention interview. During the last week of instruction, the last interview was conducted with the case study participants. The prompts for this interview are included in Appendix G. Daniel's responses follow.

When asked, "Have the interventions enhanced your motivation and mindset toward mathematics? If so, in what way? If not, why not?" he replied, "It has taught me that if I put my mind into it then I can become good at math. I haven't really tried too hard to become good at math because it is not one of my favorite subjects" (Post-interventions Interview, 11/23/2015).

Daniel indicated that the interventions taught him that he could perform well in mathematics if he was willing to work hard. However, since mathematics was not one of his favorite subjects, he did not really try hard. Daniel had assumed that in his future career as biologist, he would not need to use higher level mathematics such as pre-calculus or calculus. This notion had created a low motivation toward learning mathematics in him.

The second question in this interview was, "How do you think this experience can influence other aspects of your life, if at all?" He responded, "I think it will give me a lot of self-motivation and let me know that if I put my mind to something, then I can do it" (Post-interventions Interview, 11/23/2015). Daniel indicated that the experience of participating in the interventions had given him self-motivation. He realized that he could do anything if he decided to do so. Daniel stated that experiencing the interventions had been beneficial in all aspects of his life.

When asked, "What was the most interesting part of the interventions, if any? Explain why it was so interesting to you?" Daniel replied, "It was the fact that you have so much control over how you perceive things and how your mood towards a certain subject can actually influence the outcome, greatly" (Post-interventions Interview, 11/23/2015). Daniel stated that the most interesting part of the interventions for him was the fact that people had great control over their perceptions. He mentioned that a person's attitude toward a subject could influence one's performance on that subject. Here, Daniel had emphasized the important role of having a growth mindset in learning again.

When asked, "How has your attitude toward learning a new skill or craft changed, if at all? If so, why? If not, why not?" he responded, "I just think now that I know what I am capable of, if I do want to go out and learn something, then it won't be too hard as long as I have the right mindset going into it from the beginning" (Post-interventions Interview, 11/23/2015). In regard to his attitude toward learning a new skill, Daniel stated that he had realized with the right mindset (i.e. growth mindset), it would not be hard to learn something new and success would be accomplished.

The last question in this interview was, "What was the most important lesson that you learned from the interventions? How can it influence your future?" He replied, "Self-motivation. I know that if I motivate myself and as long as I say *I can do this*, then I will do this" (Post-interventions Interview, 11/23/2015). Daniel reflected on some of the important lessons that he had learned from the interventions. He had learned that he needed to motivate himself; telling himself that he could accomplish a task would motivate him to do so.

Daniel's overall summary. In this section, qualitative data drawn from Daniel's case regarding the fourth research question were highlighted. The evidence in this overall summary is meant to support how Daniel benefitted, if at all, from the interventions.

Daniel, who began the study with low motivation toward learning mathematics and a growth mindset toward intelligence and mathematical ability benefited in five ways from the interventions. First, he stated that the interventions had taught him that if he put his mind into learning mathematics he could be successful (Post-interventions Interview, 11/23/2015). Second, he indicated that he had learned the importance of self-motivation, practicing learned mathematics skills, and physiological reaction from the motivation interventions (Motivation Interventions, 9/21/2015). Third, from the 10 time management strategies discussed during motivation interventions, setting priorities had been the biggest time management tool for him (Motivation Interventions, 9/21/2015). Although Daniel mentioned the benefits he had gained from the motivation interventions, they did not influence his motivation toward learning mathematics. He had benefited from the motivation interventions in other aspects of his life besides mathematics learning (Written Reflection, 10/5/2015). Daniel, with a growth mindset toward intelligence and mathematical ability, knew quite well that if he was willing to work hard, he would be successful in learning any subject including mathematics. However, his damaging assumption that as a biologist he would not need to learn high-level mathematics for his future career caused him to hold a very low motivation to learn mathematics. Fourth, Daniel stated that the mindset interventions made him realize how an individual's mindset toward learning a subject could significantly influence the outcome (Post-interventions Interview, 11/23/2015). Fifth, the mindset interventions taught Daniel that with a growth mindset, learning a new skill would not be very hard (Post-interventions Interview, 11/23/2015).

The above evidence confirmed that Daniel had benefited from the interventions. Even though after the interventions his total motivation score declined similar to the trend in his group, he benefited from learning the importance of self-motivation, practicing learned mathematics skills, and the 10 time management strategies. His mindset score toward intelligence and mathematical ability stayed the same from a growth mindset on both before the interventions. Daniel's writing samples and interviews also verified his understanding in the role that mindset played in learning and achievement. However, he disclosed that the interventions had benefited him in other aspects of his life except to motivate him to learn mathematics. The argument for his lack of motivation to learn mathematics was the thought that his future career as a biologist did not need high-level mathematics.

Crystal's Case

Student background survey. Crystal was a 21-year-old, Asian female, majoring in psychology. Her high school GPA was 3.1, and she did not disclose her ACT score. This was her first time taking the pre-calculus course. She did not like group work in mathematics classes and preferred face-to-face instruction over online teaching (Student Background Survey, 8/24/2015). Crystal had a high motivation toward mathematical ability, a fixed mindset toward intelligence, and a growth mindset toward mathematical ability.

Pre-intervention interview. Crystal participated in a one-on-one interview before implementing the interventions. The prompts for this interview are included in Appendix F. When asked to compare a traditional mathematics classroom with a reformed-oriented one, indicating the advantages and disadvantage of each, she replied:

> Well, with traditional ones, you typically get a lecture and then you are assigned homework to do, afterwards. With reform-oriented, as I am in right now, it is kind of backwards. You go through the textbook at home and then you bring your questions to class, if you have any questions about how to do anything. An advantage to this is that it keeps you more involved because you are engaging with other students more, you can engage with the professor more. The disadvantage is that you don’t really have as many examples, I guess, to pull from. If you are at home and you don’t know how to do something, then, it is harder because your professor is not there; I mean, you can email them but it can be frustrating, sometimes. (Pre-interventions Interview, 9/7/2015)

She indicated that in a traditional classroom, students were taught by lectures and required to do the assigned problems at home. Alternatively, in a reformed-oriented classroom, students were asked to learn the lesson on their own at home and bring their questions to the class. She stated the advantage of the reformed-oriented classroom was the engagement of students in group work as well as with the professor. The disadvantage of the reformed-oriented mathematics classroom was that the students had to learn the lesson on their own from the textbook which might not provide enough examples and that could be frustrating at times.

When Crystal was asked, “How important is the role of mathematics in our lives?” she responded by saying:

> It is extremely important. It is pretty much involved in almost anything we do whether or not we realize it. With simple things, even like just walking to class,

> you have to divide out how much time you have and how long it takes. So, it’s just involved in everything we do, really. (Pre-interventions Interview, 9/7/2015)

Crystal indicated that mathematics played an extremely important role in our lives since it was used all the time; from simple things like figuring out how long it took to reach your classroom and how much time you had until your class started.

Then, she was asked about the most interesting topic in pre-calculus so far for her. She replied:

> So far, it is just the functions that we have been learning, because you can apply them a lot. Like with all the word problems we have been doing you realize how applicable the situations are to everyday life, careers, and everything (Pre-interventions Interview,
> 9/7/2015).

After two weeks of instruction, Crystal indicated that one of the most interesting things in the pre-calculus class so far had been using functions in the word problems. She liked the word problems because she realized how applicable the function could be in careers and in everyday life situations.

When Crystal was asked, “What motivates you to learn mathematics and why?” she responded:

> I am motivated because it is so involved in everything we do and it’s just really important for, like any type of career you want to do and to be successful, you need to know how to do these things. (Pre-interventions Interview, 9/7/2015)

The main reason that motivated her to learn mathematics was the fact that everything required knowing mathematics. Another reason for her motivation to learn mathematics was her future career in psychology.

She was then asked, “If you were to fail your first exam in pre-calculus, what strategies would you use to improve your grades?” Crystal answered:

> Well, you just study more, make sure you review the homework more, go through the study guides, ask questions, definitely, and make sure you read the textbook again. If all else fails, tutoring. (Pre-intervention Interview, 9/7/15)

If she failed the first exam in this class, her strategy to improve her grades was to study more, ask questions, review the homework problems, and read the textbook again. She indicated the last strategy to improve her grade was to seek tutoring.

Observational notes before the interventions. The experimental classroom observation took place during the third week of the semester at the class’s regular instruction time from 11:30 a.m. to 12:25 p.m. As participants entered the classroom, they noticed their name in one of the seven groups showing on the overhead projector. Every group consisted of four to five participants sitting around a circular table. The researcher chose to sit in back of the classroom where she could see and hear all of the groups.

The instructor went around to the tables asking students whether they had any questions or concerns regarding previous lessons. Then, she made the following announcement to the whole class:

> Last week we talked about linear functions and how we use them in our daily lives. Today we want to write a linear function to model a real-life situation. Look

> at the problem now showing on the overhead projector and think about it in your group.

The problem was as follows: Tim works 30 hours a week between two part-time jobs; waiter ($9.25 per hour) and math tutor ($8.50 per hour). Since he has only 30 hours each week that he can work, the more hours he spends at one job the fewer hours remain for the second job. Assume that Tim worked a total of 30 hours this week and he worked 9 hours as a waiter. How much money in total did Tim make this week? Explain how you determined your answer.

The participants started thinking and then talking amongst themselves to solve the problem. Crystal's group consisted of a male participant, a female participant, a case study participant (Adele), and Crystal. Crystal and the female participant (not Adele) were collaborating to find the model for the problem. After a while, they both nodded their heads in agreement and solved the problem.

Crystal had indicated that she did not like group work in mathematics classrooms in the student background survey. However, on this observation day she appeared to enjoy collaborating with her classmate in solving the assigned problem. Crystal did not use any language suggestive of a growth or fixed mindset on the day of observation.

Mindset interventions. During the mindset interventions, Crystal responded to the following prompts. The prompt for the initial response was: "Think about this question and reply in initial writing response part: Is your intelligence fixed (you cannot change it), or can it be improved?" Crystal responded:

> I believe intelligence can be improved, but only so with motivation. If there is a lack of motivation, intelligence levels will stay relatively the same. But with

> motivation, you can push yourself to become smarter. Some individuals are more naturally intelligent and require less motivation. (Mindset Interventions, 9/14/2015)

She stated that motivation was required to improve intelligence. With motivation, one could make an effort to increase her intelligence whereas lack of motivation prevented a person from improving her intelligence. She also indicated that some people were inherently intelligent and would require less motivation to increase their intelligence. Crystal's response demonstrated her fixed mindset toward intelligence, stating that some individuals are more intelligent than others.

At the end of the mindset interventions, the experimental group was asked to reply to the following statement as the final response: "Think about this question and reply in final writing response part: In your own words, describe a growth and fixed mindset and share your personal experience related to the effect of mindset in your life." Crystal responded with the following:

> A fixed mindset is the belief that you cannot change your abilities, and that obstacles are a sign to quit. A growth mindset believes that setbacks are chances to improve and that effort is a good thing that will lead to success regardless of the circumstances. Most of my life I have viewed obstacles as scary things that indicated I couldn't do something. Now I would like to view them as opportunities. (Mindset Interventions, 9/14/2015)

In Crystal's final response, she described a fixed and a growth mindset. She explained that a person with a fixed mindset viewed obstacles as a sign to quit; whereas a person with a growth mindset would consider setbacks and obstacles as chances to improve. She admitted that she had been intimidated by challenges before. However, after watching the TEDTalk video (Briceno, 2012), she indicated that she would like to regard obstacles as opportunities to improve. It seemed as though the mindset interventions had benefited Crystal in changing her mindset. Her perception had been changed from regarding obstacles as a sign to quit to viewing them as opportunities to excel.

The experimental group completed the last written assignment by utilizing what they learned that day to give a hopeless student (Vanessa) advice (see Appendix J). Crystal's advice to Vanessa follows:

> My advice to her would be that obstacles are a chance to get better at something. One failure is not an indicator of your abilities. The effort you place and motivation to succeed is what will get you far. You should use this opportunity to improve yourself and to remind yourself of your capabilities. (Mindset Interventions, 9/14/2015)

Her advice to Vanessa, the hopeless student, was to promote a growth mindset in herself. She advised Vanessa to use the setbacks as a chance to get better and improve herself. She indicated that in order to be successful, she needed to remind herself of her potentials, stay motivated, and to work hard. Her advice to Vanessa was indicative of a growth mindset message that she had benefited from experiencing the mindset interventions.

On the last week of Fall 2015, the results from post-mindset survey signified that Crystal's belief considering mindset on intelligence had changed from a fixed mindset to a growth mindset. She believed in a growth mindset regarding mathematical ability before the intervention and it remained the same after the interventions.

Motivation interventions. The experimental group participated in the motivation interventions (see Appendices H and I). These interventions were implemented one week after the mindset interventions (9/21/2015). One of the assignments was to reflect on the following statement: "In your own words, explain how you can improve your self-efficacy in learning mathematics. From the four ways discussed to improve self-efficacy, which one has been the most effective for you?" The following was Crystal's response:

> Two of the strategies to improve self-efficacy that would be effective for myself in math are the enactive mastery and becoming aware of my physiological responses. When I feel discouraged by my abilities, I tend to become very intimidated by a task. By acknowledging what I did right, I can reassure myself of my abilities. This in turn affects my physiological responses. I tend to get anxious with difficult tasks, and becoming aware of my tendencies when I am anxious will help me in stopping myself from engaging in any negative habits that interfere with my success. (Motivation Interventions, 9/21/2015)

From the four sources to improve self-efficacy (i.e., enactive mastery, vicarious experiences, verbal persuasion, and physiological reaction), she picked the enactive mastery (i.e., past successful experiences) and physiological reaction (i.e., to perceive emotional states with optimism or a positive mood) as the most helpful. She explained that she was intimidated by difficult tasks and what could help her would be thinking about her past successful experiences and avoiding negative thoughts. Crystal benefited from the motivation interventions in learning about the four sources of attaining self-efficacy in learning mathematics.

The second assignment for motivation interventions was to reflect on the following statement: “Think about this question and reply in time management response part: In your own words, explain how you can improve your time management. From the 10 strategies suggested in the article (see Appendix I) to improve time management, which one has been the most effective for you?” Crystal’s response follows:

> The strategy that would help my time management skills the most would be managing external time wasters. I have a bad habit of letting things take way longer than they should as I get carried away with the current situation. If I set aside specific times to accomplish any tasks it may help me manage these activities and to not spend all night on something that should only have an hour devoted to it. (Motivation Interventions, 9/21/2015)

From the 10 strategies discussed in the article, Crystal stated that “managing external time wasters” was the most effective way of time management for her. She indicated that to better manage external time wasters she needed to set specific times to accomplish each task and to abide by her own timelines.

Crystal’s pre-total motivation score was 85, about one standard deviation above the experimental class mean (M = 71.27, SD = 11.91). Even though on the average, the post-total motivation scores in the experimental group declined compared to their respected pre-scores (M = 66.74, SD = 16.86), Crystal’s post-total motivation score increased by one point to reach 86. Crystal’s choice for promoting her self-efficacy was enactive mastery which, in general, was the most influential source of self-efficacy (Bandura, 1997).

Written reflection. Two weeks after the experimental group's participation in the interventions, the case study participants were asked to reflect on their recent experience by responding to the questions in Appendix L. In this section, Crystal's responses are presented.

In response to the question regarding whether her motivation toward learning mathematics had changed any, she replied: "I have learned to not give up and to keep trying to learn something even if I do not completely understand it" (Written Reflection, 10/5/2015).

Crystal had learned not to surrender and to keep trying to learn mathematics even though she might not comprehend it completely. In this response, Crystal's language was suggestive of her growth mindset, the outcome that she had benefited from interventions.

When asked, "How have the motivation interventions promoted your interest in learning mathematics?" she replied:

> They reminded me of how capable we are as humans to learn and excel in new things. Certain sections of math can be extremely challenging but the motivation interventions reminded me of how, though difficult, it is still possible as long as you try. (Written Reflection, 10/5/2015)

The motivation interventions helped her to remember that humans have the ability to learn new things and improve themselves. Crystal learned that she could succeed in learning mathematics as long as she tried; even though it had been extremely challenging for her at times. Crystal had perhaps increased her motivation to learn mathematics by holding a growth mindset.

When asked about the lesson that she learned during the mindset interventions that surprised her, she replied, “I did not realize the extent to which one can excel at something purely by having a positive mindset about themselves and their learning capabilities” (Written Reflection, 10/5/2015). She was surprised to learn that having a positive mindset (i.e., a growth mindset) could have a great impact on individuals and their learning abilities. Crystal with a fixed mindset toward intelligence had benefited from learning about the direct relationship between an individual’s growth mindset and his learning outcomes.

Crystal was asked about the impact of an individual’s mindset about intelligence on his/her learning. She responded, “If you believe that your intelligence is not fixed and that you can do plenty to make it better, you will be better at learning (as you will not give up when things may become challenging)” (Written Reflection, 10/5/2015). She explained that the impact of an individual’s mindset on his/her learning could result in improving one’s intelligence. If people believed that their intelligence was not fixed and it could be improved by making an effort and not giving up, they would be better at learning. Crystal’s response to this question had demonstrated a change in her mindset toward intelligence, from a fixed to a growth mindset.

When asked about how her experience during interventions had changed her perception toward learning in general, she replied:

> I now realize how capable I am of improving my skills and becoming better at things I may have always struggled with. I do not have to always struggle with these things just as long as I put forth the effort to try and do well. (Written Reflection, 10/5/2015)

Crystal acknowledged that she now realized the improvement in her learning could be made by making an effort and trying her best. She also realized that she did not need to struggle with challenges in learning as long as she used them to excel. Crystal had now realized the important role of possessing a growth mindset and its benefits in learning.

Post-intervention interview. During the last week of instruction, the last interview was conducted with the case study participants. The prompts for this interview are included in Appendix G. Crystal's responses follow.

When asked, "Have the interventions enhanced your motivation and mindset toward mathematics? If so, in what way? If not, why not?" she replied:

> I think it has because it makes you see that you can actually apply things to yourself if you believe in yourself and believe you can actually learn. If you stay motivated, you can apply that instead of just giving up and letting roadblocks stop you from getting further in the area of math. (Post-interventions Interview, 11/23/2015)

Crystal stated that the interventions had enhanced her motivation and mindset toward mathematics. These interventions made her realize that to succeed in learning, she needed to stay motivated, believe in her capabilities, and prevent obstacles from stopping her. Clearly, she understood how the interventions could be beneficial in promoting her motivation and mindset toward learning mathematics.

The second question in the interview was: "How do you think this experience can influence other aspects of your life, if at all?" She responded, "I think you can apply it to anything, really, like anything you want to learn or attempt to be good at. Just because you are not naturally good at it does not mean you can't do it" (Post-interventions

Interview, 11/23/2015). She indicated that experiencing the interventions had impacted all aspects of her life. The interventions had influenced the way she thought about learning and made her realize that she could learn anything she intended to learn. Crystal's experience during interventions had taught her that everybody could excel in their performance at a task with hard work. Moreover, she now had realized that her assumption that some individuals were naturally good at something was not valid.

When asked, "What was the most interesting part of the interventions, if any? Explain why it was so interesting to you," Crystal replied:

> You can be in control of so many of these skills. Many people would think, I guess, that if you are not naturally good at something, then that is something you just can't really do but if you just change your mindset, you can do so much more with your life. That's not something that everyone will realize. (Post-interventions Interview, 11/23/2015)

The most interesting part of the intervention for Crystal was the realization of the fact that if she was not good at something, with the right mindset (i.e., the growth mindset) she could improve her skill in that area. In this response, she demonstrated her awareness in the prominent role that a growth mindset plays in learning.

When asked, "How has your attitude toward learning a new skill or craft changed, if at all? If so, why? If not, why not?" she responded:

> I am more optimistic about learning new things. I think I have more of an ability to do these things now instead of just turning my head away. I think I can actually try new things and I'm more willing to do so. (Post-interventions Interview, 11/23/2015)

She was more optimistic toward learning a new skill after the interventions than before. Crystal realized that she was more confident in learning new things now instead of rejecting them. Individuals with a growth mindset are more optimistic in learning a new skill since they know success is achievable with perseverance and hard work.

The last questions in this interview were: “What was the most important lesson that you learned from the interventions? How can it influence your future?” She replied, “You can really do anything you set your mind capable if you think you can. You just have to believe in yourself. It is kind of like the power of positive thinking can take you far in life” (Post-interventions Interview, 11/23/2015). Crystal reflected on the important lessons that she had learned from the interventions. She learned that believing in herself and her abilities, similar to positive thinking (i.e., having a growth mindset), could greatly influence her life.

Crystal’s overall summary. In this section, qualitative data drawn from Crystal’s case regarding the fourth research question were highlighted. The evidence in this overall summary is meant to support how Crystal benefitted, if at all, from the interventions.

Crystal, who began the study with high motivation toward learning mathematics, a fixed mindset toward intelligence, and a growth mindset toward mathematical ability, benefited in six ways from the interventions. First, Crystal indicated that she had benefited from learning the 10 strategies for time management. She stated that the tip about “managing external time wasters” would help her manage her time wisely (Motivation Interventions, 9/21/2015). Second, she stated that the interventions had taught her to stay motivated rather than giving up when confronted with obstacles in learning a subject including mathematics (Post-interventions Interview, 11/23/2015).

Third, the interventions had reminded her that even though certain sections of mathematics were challenging, it was still possible to learn them as long as she tried (Written Reflection, 10/5/2015). Fourth, Crystal stated that the mindset interventions had changed her perspective regarding obstacles. She stated that most of her life, she had viewed obstacles as things to avoid, but now she considered them as opportunities to learn (Mindset Interventions, 9/14/2015). Fifth, she had learned that individuals with a growth mindset could excel and improve their skills and learning capabilities (Written Reflection, 10/5/2015). Sixth, after experiencing the mindset interventions she realized that if an individual was not, in her words "naturally good at something" (Post-interventions Interview, 11/23/2015), success could still be achieved by not giving up and making an extra effort to learn. The lessons learned that Crystal communicated during interventions, post-interventions interview, and written reflection were all indicative of the benefits of exhibiting a growth mindset.

The above evidences confirmed that Crystal had benefited from the interventions. Her total motivation score increased by one point, unlike the decreasing trend in her group after the interventions. Her mindset toward intelligence changed from a fixed mindset to a growth mindset after the interventions. Her mindset toward mathematical ability stayed as a growth mindset after the interventions. Crystal's writing samples and interviews demonstrated her understanding in the role that mindset plays in learning and achievement. She stated that the mindset interventions had changed her perspective regarding obstacles as things to avoid to opportunities to learn and excel.

Marge's Case

Student background survey. Marge was a young biracial female, majoring in biochemistry. Her high school GPA was 4.0. She did not disclose her age and score on the ACT. This was her first time taking the pre-calculus course. She liked group work in mathematics classes and preferred face-to-face instruction over online teaching (Student Background Survey, 8/24/2015). Marge had a high motivation toward learning mathematics, and a growth mindset toward intelligence and mathematical ability.

Pre-intervention interview. Marge participated in a one-on-one interview before implementing the interventions. The prompts for this interview are included in Appendix F. When asked to compare a traditional mathematics classroom with a reformed-oriented one, indicating the advantages and disadvantage of each, she replied:

> The traditional is more individual work because you are by yourself, mainly, and you are trying to work with your own skills. The reform is a group effort so, if you have a problem and the teacher is too busy, you can ask someone else. It helps you build bonds with your classmates and it helps you with your work. (Pre-interventions Interview, 9/7/2015)

Marge described the traditional classroom as a place that students worked on their own learning skills; whereas in a reformed-oriented one they were learning collectively since students performed group work. She indicated that one of the advantages of a reformed classroom was building bonds between classmates as they helped each other learn the material.

When Marge was asked, "How important is the role of mathematics in our lives?" she responded by saying, "I think it is very important because we use it every day, when we cook, when do homework, when we learn different subjects, you have to, basically, apply it to everything we do in life" (Pre-interventions Interview, 9/7/2015). Marge stated that mathematics played an important role in our lives because it was basically used in everything we did in life including cooking, doing homework, and when learning other disciplines.

Then, she was asked about the most interesting topic in pre-calculus so far for her. She replied, "I would say learning how to graph equations. I am not really a math student, if you put it like that; I am more of a science student. So, when she taught me ways I could get information and graph, I thought it was pretty cool" (Pre-interventions Interview, 9/7/2015). After two weeks of instruction, Marge indicated that one of the most interesting things in pre-calculus class so far had been how to graph equations. As a science student, she enjoyed learning how to obtain information from the graph of a function.

When Marge was asked, "What motivates you to learn mathematics and why?" she responded, "Well, of course, my major because I am majoring in biochemistry and I am going to be a doctor. Really what motivates me is my weakest subject and I want to improve my skills so I can overcome my weak points. My math skills are very weak" (Pre-interventions Interview, 9/7/2015). The main reason that motivated her to learn mathematics was the fact that mathematics was her weakest subject. Another reason for her motivation to learn mathematics was her future career in medicine.

She was then asked, "If you were to fail your first exam in pre-calculus, what strategies would you use to improve your grades?" Marge answered:

> If I fail my exam, I would probably go to tutoring every day and try to get as much information as I can. I would talk to the teacher, one on one, after class and see what she says or I could just meet with some of my classmates and do a study group so they could teach me for my point of view. (Pre-intervention Interview, 9/7/15)

If she failed the first exam in this class, her strategies to improve her grades were to seek tutoring, get advice from the teacher, form a study group with classmates, and learn from them.

Observational notes before the interventions. The experimental classroom observation took place during the third week of Fall semester 2015 at the class's regular instruction time from 11:30 a.m. to 12:25 p.m. As participants entered the classroom, they noticed their name was in one of the seven groups showing on the overhead projector. Every group consisted of four to five participants sitting around a circular table. The researcher chose to sit in back of the classroom where she could see and hear all of the groups.

The instructor went around to the tables, asking students whether they had any questions or concerns regarding previous lessons. Then she made the following announcement to the whole class:

> Last week we talked about linear functions and how we use them in our daily lives. Today we want to write a linear function to model a real-life situation. Look at the problem now showing on the overhead projector and think about it in your group.

The problem was as follows: Tim works 30 hours a week between two part-time jobs; waiter ($9.25 per hour) and math tutor ($8.50 per hour). Since he has only 30 hours each week that he can work, the more hours he spends at one job the fewer hours remain for the second job. Assume that Tim worked a total of 30 hours this week and he worked 9 hours as a waiter. How much money in total did Tim make this week? Explain how you determined your answer.

The participants started thinking and then talking amongst themselves to solve the problem. Marge's group consisted of two male participants, two female participants, and Marge. Marge and one of the male participants were talking about their way of solving the assigned problem. She wanted to find a general linear equation that could model the problem when Tim worked different hours as a waiter. However, the rest of the group focused on finding the answer to this problem.

In the student background survey, Marge had indicated that she liked group work in mathematics classrooms. She appeared relaxed as she collaborated with her classmates on solving the problem. She was even interested to go beyond the scope of the assigned problem. On the day of observation, she did not use any language suggestive of a growth or fixed mindset.

Mindset interventions. During the mindset interventions, Marge responded to the writing prompts. The prompt for the initial response was: "Think about this question and reply in initial writing response part: Is your intelligence fixed (you cannot change it), or can it be improved?" Marge responded:

> I believe that your intelligence can't be changed but it can be impacted. If your lowest or weakest subject is math, I feel like you can't stop it from being your

> weakest subject but you can improve your skills to learn better and pass the class.
>
> (Mindset Interventions, 9/14/2015)

She stated that people could influence their intelligence if they were willing to do so. Marge felt that even while dealing with one's weakest subject, a person could improve and excel in acquiring that skill. Marge had indicated her weak background in mathematics in pre-interventions interview. Here, she confirmed her growth mindset by expressing the willingness to work hard to achieve success in this course.

At the end of the mindset interventions, the experimental group was asked to reply to the following statement as the final response: "Think about this question and reply in final writing response part: In your own words, describe a growth and fixed mindset and share your personal experience related to the effect of mindset in your life." Marge responded with the following:

> Growth mindset is a mind willing to accept new challenges. Fixed mindset is a mind not willing to accept new challenges. My experience is these fixed mindset are with math. No matter how hard I try I always seem to fail so I believe that I'm not a math person.
>
> (Mindset Interventions, 9/14/2015)

In Marge's final response, she described a fixed and growth mindset. She explained that a person with a fixed mindset was not prepared to undertake new challenges, whereas a person with a growth mindset would consider enduring challenges. She admitted that she had experienced a fixed mindset toward mathematical ability, believing at times that she could not be good at mathematics.

The experimental group completed the last written assignment by utilizing what they learned that day to give a hopeless student (Vanessa) advice (see Appendix J). Marge's advice to Vanessa follows:

> Vanessa has a fixed mindset because she was praised about how good she was in math. So what I would tell her is that even if [you] were good in high school this is a whole new level and you need to try harder and believe you can do better on the next exam and don't let one test deter your ability to learn. (Mindset Interventions, 9/14/2015)

She stated that Vanessa had a fixed mindset toward mathematical ability because she was praised for being good at it. Her first advice to Vanessa, the hopeless student, was to let her know that college was much different from high school. Her second advice was to study harder, believe in doing better on the next exam, and not be discouraged by the outcome of one test. Marge's advice meant to introduce some of the messages of having a growth mindset to Vanessa. She wanted her to accept new challenges, make an extra effort in learning, and believe in herself.

On the last week of Fall 2015, the results from post-mindset survey signified that Marge's belief considering mindset on intelligence and mathematical ability had not changed from a growth mindset. She believed in a growth mindset regarding intelligence and mathematical ability before and after the interventions.

Motivation interventions. The experimental group participated in the motivation interventions (see Appendices H and I). These interventions were implemented one week after the mindset interventions (9/21/2015). One of the assignments was to reflect on the following statement: "In your own words, explain how you can improve your self-efficacy in learning mathematics. From the four ways discussed to improve self-efficacy, which one has been the most effective for you?” The following was Marge’s response:

> I could improve my self-efficacy in mathematics by starting to apply myself more in my studies. Instead of having a negative emotion about the subject I should take on the challenge and believe that I can overcome the challenge that is mathematics. (Motivation Interventions, 9/21/2015)

From the four sources to improve self-efficacy (i.e., enactive mastery, vicarious experiences, verbal persuasion, and physiological reaction), she picked the physiological reaction (i.e., to perceive emotional states with optimism or a positive mood) as the most helpful. She explained that to improve her self-efficacy in mathematics, she needed to confront the challenges of learning mathematics with an optimistic view (i.e., a growth mindset) rather than negative emotions (i.e., a fixed mindset). Marge’s choice to improve her self-efficacy in mathematics was aligned with having a growth mindset toward mathematical ability.

The second assignment for motivation interventions was to reflect on the following statement: “Think about this question and reply in time management response part: In your own words, explain how you can improve your time management. From the 10 strategies suggested in the article (see Appendix I) to improve time management, which one has been the most effective for you?” Marge’s response follows:

> I can improve my time management by stop trying to multi-task. I need to stop trying to do everything at once so I can have more free time. I need to take my time doing so I can understand it better. The most effective way for me to get better is by using a weekly schedule. (Motivation Interventions, 9/21/2015)

From the 10 strategies discussed in the article, Marge stated that "using a planning tool" such as a weekly schedule was the most effective way of time management for her. Another strategy that could improve her time management was "avoid multi-tasking." She noted that with this strategy, she could have more free time and comprehend what she had done better.

Marge's pre-total motivation score was 84, about one standard deviation above the experimental class mean (*M* = 71.27, *SD* = 11.91). On average, the post-total motivation scores in the experimental group declined compared to their respected pre-scores (*M* = 66.74, *SD* = 16.86). Marge's post-total motivation score decreased to 75.

Written reflection. Two weeks after the experimental group's participation in the interventions, the case study participants were asked to reflect on their recent experience by responding to the questions in Appendix L. In this section, Marge's responses are presented.

In response to the question regarding whether her motivation toward learning mathematics had changed any, she replied: "Yes, because I feel like since I change my studying habits I'm learning better" (Written Reflection, 10/5/2015). Marge stated that her motivation toward learning mathematics had changed. She was learning better since she had changed her study habits. It appeared that her motivation toward learning mathematics had changed due to changing her study habits. She may have benefited from the motivation interventions in changing her study habits, promoting superior mathematical learning.

When asked, "How have the motivation interventions promoted your interest in learning mathematics?" she replied, "It showed me how to change my mindset and try to better myself to push myself harder to overcome my challenge" (Written Reflection, 10/5/2015). Here, she was actually referring to how mindset interventions had helped her reinforce her growth mindset, in making efforts to improve and to persevere until she had achieved success. This response was an indication of her growth mindset toward mathematical ability.

When asked about the lesson she learned during the mindset interventions that surprised her, she replied, "That people with fixed mindsets continue to fail while people with a growth mindset push themselves harder to accomplish the challenge" (Written Reflection, 10/5/2015).

Marge was surprised to learn the impact of mindset on people and their learning abilities. In her opinion, people with a fixed mindset would surrender and fail, whereas people with a growth mindset would achieve their goals by perseverance. She had clearly benefited from learning the results of the research that had been done on students with different mindsets during the mindset interventions.

Marge was asked about the impact of an individual's mindset about intelligence on his/her learning. Marge responded, "A fixed mindset causes the learner to not try to learn the material and a growth mindset causes the learner to push themselves harder to overcome their challenges" (Written Reflection, 10/5/2015). She explained the direct impact of an individual's mindset on his/her learning. She indicated that people with a fixed mindset would not attempt to learn the material, but people with a growth mindset made efforts to improve until they had achieved success in learning.

When asked about how her experience during interventions had changed her perception toward learning in general, she replied, "It changed my mindset from fixed to growth because they made me feel that I can overcome my challenges" (Written Reflection, 10/5/2015).

Marge acknowledged that her experience during the interventions had changed her perception toward learning in general. She stated that this experience enabled her in believing that she could conquer her challenges. Her response to this question illustrated the benefits that she had gained from the mindset interventions.

Observational notes after the interventions. During the eighth week of instruction, the observational notes were collected by observing the experimental group especially the case study participants. This observation occurred during instruction time from 11:30 a.m. to 12:25 p.m. The participants came to the classroom, and then looked for their assigned group, which was projected by overhead on the whiteboard. The instructor went around to the tables asking students whether they had any questions or concerns regarding previous lessons. Then, she made the following announcement to the whole class:

> Last time we started a new chapter talking about Trigonometric Functions. We talked about the two mostly used measurements for an angle, radians, and degrees, and how they are related. Let's look at this problem: April is riding on a circular Ferris wheel that has a radius of 51 feet. After boarding the Ferris wheel, she traveled a distance of 32.2 feet along an arc before the Ferris wheel stopped for the next rider.
>
> a) Making a drawing of the situation and illustrate the relevant quantities.
>
> b) The angle that April swept along the arc had a measure of
>
> i) how many radians?

ii) how many degrees?

Marge's group consisted of one male participant, two female participants, and Marge. Marge drew a big Ferris wheel and then wrote the measurements for the radius and the arc that April traveled. The rest of the group made their drawings, too. One of the female participants asked Marge about solving the second part of the problem. She replied that since the measurement of the central angle would always be proportional to the arc it intercepted, they needed to use the related formula. Once the angle was found in radians, it could be converted to degrees, too. With her help, the group found the formulas and solved the problem.

Marge appeared interested in solving the assigned problem and was helping the rest of the participants in the group to understand the problem. She did not use a language suggestive of a growth/fixed mindset on the day of observation.

Post-intervention interview. During the last week of instruction, the last interview was conducted with the case study participants. The prompts for this interview are included in Appendix G. Marge's responses follow.

When asked, "Have the interventions enhanced your motivation and mindset toward mathematics? If so, in what way? If not, why not?" she replied:

> It motivated me. Before the interventions, I thought I couldn't learn math. I thought math was my weakest subject but, as I started reading the time management and all, it helped me. My grades started going up and it made me believe I can do math.
>
> (Post-interventions Interview, 11/23/2015)

Marge stated that the interventions had enhanced her motivation and mindset toward mathematics. The interventions had motivated her to play a more active role in her learning. She acknowledged that since mathematics has been her weakest subject, before the intervention, she thought that she could not learn mathematics. However, after the interventions, she used the facts and strategies discussed during interventions, like time management tips, which promoted her grades and her confidence in learning mathematics. In response to this question, Marge demonstrated how she had benefited from the motivation interventions in the light of her learned lessons from the mindset interventions, holding a growth mindset.

The second question in this interview was, “How do you think this experience can influence other aspects of your life, if at all?” She responded, “I think it will make me more motivated to learn different things that I might find difficult. It will make me enhance it better than I am” (Post-interventions Interview, 11/23/2015). Marge indicated that experiencing the interventions had motivated her to try learning new skills, something that she was intimidated to do before the interventions. She stated that this newfound attitude would enhance other aspects of her life.

When asked, “What was the most interesting part of the interventions, if any? Explain why it was so interesting to you,” Marge replied, “I would say the fixed mindset and growth mindset. The fixed mindset showed that their grades drop and they just gave up. With the growth mindset, they overcome the obstacles that they face” (Post-interventions Interview, 11/23/2015).

The most interesting part of the intervention for Marge was the message of TEDTalk video (Briceno, 2012), about a fixed/ growth mindset. On this video, the results of the studies on students with different mindsets indicated that students with a fixed mindset experienced a decline in their grade whereas the students with a growth mindset enjoyed an improvement in their grades.

When asked, “How has your attitude toward learning a new skill or craft changed, if at all? If so, why? If not, why not?” she responded, “My attitude changed, positively because I feel like I can overcome new obstacles now. I learned how to manage my time better. I feel I can learn some new skills now” (Post-interventions Interview, 11/23/2015). Marge indicated that her attitude toward learning a new skill had changed after the interventions. Marge felt prepared to learn new skills since she had learned how to manage her time wisely, and how to achieve success with perseverance. Evidently, she had benefited from the mindset interventions that reinforced her growth mindset perspective on learning new skills, to feel prepared confronting the challenges.

The last questions in this interview were, “What was the most important lesson that you learned from the interventions? How can it influence your future?” She replied, “The most important thing I learned was time management. Being a college student and working, I have to balance my social life and everything with my schoolwork. So, time management was the most important” (Post-interventions Interview, 11/23/2015). Marge reflected on the important lessons that she had learned from the interventions. She indicated that instructions in the article “10 Strategies for Better Time Management” (see Appendix I) were the most important lessons that she had learned during the interventions. The time management tips had helped her balance her school work and social life. The time management strategies, as a part of the motivation interventions, were beneficial to Marge in managing her time wisely at home and school, but her post-total motivation score did not increase.

Marge's overall summary. In this section, qualitative data drawn from Marge's case regarding the fourth research question were highlighted. The evidences in this overall summary are meant to support how Marge benefitted, if at all, from the interventions.

Marge, who began the study with high motivation toward learning mathematics and a growth mindset toward intelligence and mathematical ability, benefited in six ways from the interventions. First, she stated that the interventions had motivated her to learn mathematics. She indicated that before the interventions, mathematics had been her weakest subject. However, now with increased motivation, using time management tips, and studying more, her grades in mathematics had improved (Post-interventions Interview, 11/23/2015). Second, Marge indicated that the interventions had taught her to apply herself more, take on the challenges, and believe in herself in overcoming the obstacles of learning mathematics (Motivation Interventions, 9/21/2015). Third, she stated that the most important lesson that she had learned from the interventions had been time management strategies (Post-interventions Interview, 11/23/2015. Marge indicated that from the 10 time management tips, using a weekly schedule and avoiding multi-tasking were the most effective for her (Motivation Interventions, 9/21/2015). Fourth, Marge stated that the interventions taught her that individuals with a fixed mindset continue to fail while the ones with a growth mindset strive harder to accomplish the challenges (Written Reflection, 10/5/2015). Fifth, her attitude toward learning a new skill or craft changed. She indicated that after experiencing the interventions she could now overcome the obstacles of learning a new skill (Post-interventions Interview, 11/23/2015). The six ways that Marge benefited from experiencing the interventions reinforced her high motivation toward learning mathematics and her growth mindset toward intelligence and mathematical ability.

The above evidences confirmed that Marge had benefited from the interventions. Although, after the interventions, her total motivation score declined similar to the trend in her group, her grades in mathematics had improved. She benefited from motivation interventions by learning to study more to learn mathematics and using the 10 time management tips. Her mindset toward intelligence and mathematical ability stayed the same as a growth mindset after the interventions. Marge's writing samples and interviews demonstrated her understanding in the role that mindset played in learning and achievement. She stated that the mindset interventions had changed her perspective regarding learning a new skill. After experiencing the interventions, she felt prepared to overcome the obstacles of learning a new skill or craft.

Case Study Participants with a Growth Mindset

The fourth research question in this study was aimed to investigate the usefulness of interventions for participants of different mindset and/or motivation in a reformed pre-calculus classroom. This section will compare and contrast how the case study participants with a growth mindset responded and reflected on interventions based on student background survey, pre- and post-interventions interviews, classroom observational notes before and after interventions, written responses from the mindset and motivation interventions, and their written reflection.

Similarities. There were six similarities between Marge and Daniel who both possessed a growth mindset on intelligence and mathematical ability, as they reflected on interventions. First, they both believed that all things, including intelligence and mathematical abilities, could be improved by hard work and the willpower to succeed (Mindset Interventions, 9/14/2015). Second, Marge and Daniel's motivation to learn mathematics appeared to be driven by their career path. They both indicated that their motive to learn mathematics was related to their future career (Pre-intervention Interview, 9/7/15). Third, based on their "final writing response" in the mindset intervention, they shared the same definition for a growth /fixed mindset. They both described a person with a growth mindset as someone who was willing to accept new challenges and improve. In their opinion, a person with a fixed mindset was content with his limits and was not willing to accept new challenges. The fourth similarity between the two case study participants with a growth mindset revealed that they had had a fixed mindset in regards to learning mathematics sometimes in their academic life (Mindset Interventions, 9/14/2015). Fifth, Marge and Daniel both indicated that the best way for them to promote self-efficacy in learning mathematics was to perceive their emotional states with optimism and positive mood (Motivation Interventions, 9/21/2015). Sixth, the most interesting part of the interventions for both case study participants was recognizing how an individual's perception toward a certain subject can significantly impact learning (Post-interventions Interview, 11/23/2015).

Differences. Marge and Daniel had three differences despite both having a growth mindset toward intelligence and mathematical ability. The observational notes indicated that Marge was extremely active in contributing to classroom group work.

However, Daniel was quiet, did not participate in the conversations of his classmates, and worked on the assigned problem on his own (Observational notes, 9/10/15 and 10/14/15).

The second difference was Marge and Daniel's assumption regarding how much mathematics their future careers needed. Marge, a biochemistry major who planned to be a medical doctor, acknowledged the important role of mathematics in her future career (Pre-intervention Interview, 9/7/15). However, Daniel, a biology major who intended to work on animals, believed his future career would not demand the mathematical skills acquired in pre-calculus or calculus classrooms (Pre-intervention Interview, 9/7/15). Therefore he did not truthfully attempt to become good at mathematics (Post-interventions Interview, 11/23/2015).

The third difference between Marge and Daniel was the lesson learned from the interventions. Marge indicated that the most important lesson that she learned from the interventions was time management: how to balance schoolwork, work, and her social life. Daniel stated that self-motivation was the most important lesson that he had learned from the interventions. He explained that by motivating himself to accomplish a task, he could get it done (Post-interventions Interview, 11/23/2015).

Case Study Participants with a Fixed Mindset

In this section the effectiveness of interventions for the case study participants possessing a fixed mindset is examined. This section intends to compare and contrast how the case study participants with a fixed mindset responded and reflected on interventions based on student background survey, interviews before and after the interventions, classroom observational notes before and after the interventions, written responses from mindset and motivation interventions, and their written reflection.

Similarities. Adele had a fixed mindset toward intelligence and mathematical ability. Crystal had a fixed mindset on intelligence but a growth mindset on mathematical ability. These two case study participants had five similarities. First, the main motive for learning mathematics for Adele and Crystal was to be successful in their future careers (Pre-intervention Interview, 9/7/15). Second, they both indicated that some individuals are naturally more intelligent than others (Mindset Interventions, 9/14/2015). The third similarity was that they both admitted experiencing a fixed mindset toward learning a subject when confronted with obstacles (Mindset Interventions, 9/14/2015). Fourth, the most interesting part of the interventions for both case study participants was learning about the message of the TEDTalk video (Briceno, 2012). This message made them realize the enormous influence of mindset on how an individual learns (Post-interventions Interview, 11/23/2015). One of the lessons learned from this message was the acknowledgement of a change in their perception toward learning in general. Their new perception in learning enabled them to view obstacles as opportunities to advance, make efforts and to believe in themselves (Written Reflection, 10/5/2015). The fifth similarity was that they both indicated that the interventions had enhanced their motivation and mindset toward learning mathematics (Post-interventions Interview, 11/23/2015).

Differences. Adele and Crystal had three differences. The first difference between the two case participants with a fixed mindset on intelligence was that Adele liked the group work in mathematics classes but Crystal did not. The second difference was their preference in choosing the strategy to improve their self-efficacy. Adele stated peer modeling was the most effective strategy for improving her self-efficacy, while

Crystal chose the enactive mastery and physiological reaction as the two strategies that were effective in improving her self-efficacy.

The third difference was in their response regarding time management strategies. Adele stated that to manage her time wisely she needed to write down everything in her planner and not to procrastinate. Crystal indicated the strategies that would help her time management skills were managing external time wasters and setting specific times for every task.

Cross-case Comparison

In this study, the effectiveness of interventions for participants of different mindsets and/or motivation in a reformed pre-calculus classroom was examined to find answers for the fourth research question. This section will investigate some of the similarities and differences in which case study participants of various mindset and/or motivation benefited, if at all, from the interventions. This cross-case comparison is based on student background survey, pre- and post-interventions interviews, their written reflections, observational notes before and after interventions, and written responses from mindset and motivation interventions.

Cross-case similarities. There were three similarities among the four case study participants. First, the most interesting part of the interventions for all case study participants was the message of TEDTalk video (Briceno, 2012), indicating how an individual's perception toward a subject can significantly influence learning (Post-interventions Interview, 11/23/2015). Second, they all indicated that the interventions had enhanced their motivation and mindset toward learning in general, including mathematics (Post-interventions Interview, 11/23/2015). The third similarity was the fact that they all had experienced having a fixed mindset toward a subject in their academic life (Mindset Interventions, 9/14/2015).

Cross-case differences. There were two differences between the two groups. First, the most important lesson learned for the group with a growth mindset was time management and self-motivation, while for the case study participants with a fixed mindset it was the enormous influence of possessing a growth mindset on learning (Post-interventions Interview, 11/23/2015). Second, the strategies to improve self-efficacy for the group with a fixed mindset were peer modeling, enactive mastery, and physiological responses. Alternatively, the only strategy that was useful in improving the self-efficacy of the case study participants with a growth mindset was physiological responses (Motivation Interventions, 9/21/2015).

Chapter Summary

In this chapter the quantitative and qualitative data to answer the four research questions in this study were examined. The quantitative data were intended to address the first three research questions, while the analyzed qualitative data provided in-depth answers to the fourth research question. The quantitative results included comparing scores from the experimental and control groups on pre- and post-PCA, SMQ-II, and the Mindset Survey. The qualitative results were used to examine how the four case study participants of different mindset and/or motivation benefited, if at all, from the interventions.

CHAPTER FIVE: SUMMARY AND DISCUSSION

Introduction

One of the national priorities in U.S. education is to produce an adequate number of skilled STEM graduates to meet the rising demand in the 21st century workforce (Wang, 2010). Once a leader in STEM education, the U.S. is now considerably behind many countries on several accounts, including the inadequate number of STEM graduates and the low performance of American students in worldwide competition in science and mathematics (PCAST, 2010). The majority of studies aimed at improving STEM education have focused on the importance of cognitive factors such as the mathematics courses taken by students, ACT scores, and high school GPA. However, this study sought to examine the role of two non-cognitive factors (i.e., motivation and mindset) in the performance of college students majoring in STEM fields.

The purpose of this mixed-methods study was to examine the influence of motivation and mindset interventions on students majoring in STEM fields for enhancing and improving students' success in their pre-calculus course. The following research questions were addressed:

1. Do students in a reformed class who receive motivation and mindset interventions perform significantly better on a pre-calculus achievement test compared to students in a similar class who do not receive such interventions?
2. Do students in a reformed class who receive motivation and mindset interventions show significant improvement in motivation towards mathematics compared to students in a similar class who do not receive such interventions?

3. Is there a difference in the proportion of students in groups with either a growth or a fixed mindset depending on condition at post-test? Does the proportion of students in the experimental group change from a fixed vs. a growth mindset from pre-to post-interventions?
4. How do individuals of different mindset and/or motivation benefit, if at all, from the interventions?

In the following sections, the methodology and the findings of this study described in Chapters Three and Four, respectively, are reviewed. The second section includes the discussion of quantitative and qualitative results pertaining to the research questions mentioned above. Then, implications of this study, suggestions for future research, and a summary of this chapter follow.

Review of the Methodology

Design

In this study a mixed methods design was used. This design focused on understanding the previously stated research questions more completely by collecting and analyzing data, using both quantitative and qualitative methods, in a single study (Creswell & Plano Clark, 2007). To gather qualitative data for answering the fourth research question, explanatory case studies were utilized. This is because *how* and *why* questions handle situations that need to be tracked over time rather than explored as simple occurrences or frequencies (Yin, 2009). In order to build an advanced mixed methods research design, adding an intervention design was essential. The goal of this design was to study the fourth research question by implementing an intervention and then combining the quantitative results with qualitative data (Creswell, 2015).

Participants

Two sections of a reformed pre-calculus course with the same instructor were considered for this study in Fall 2015. The experimental group had 30 students and the control group had 31 students. The selection of groups was made according to the overall students' scores on the mindset and motivation pre-tests. The section with lower scores in both areas was assigned as the experimental group. The make-up of the experimental and the control groups closely resembled that of the university and the participants were taking their first mathematics course at the university. Four students were purposefully selected from the experimental group to serve as the cases within the case study to help explain the quantitative data. Selection of the four students was based on the scores from the two factors of mindset and motivation toward learning mathematics. The characteristics of case study participants were as follows: one with a fixed mindset and low motivation toward mathematics; one with a fixed mindset and high motivation toward mathematics; one with a growth mindset and low motivation towards mathematics; and one with a growth mindset and high motivation towards mathematics.

Data Sources

This mixed methods study used both quantitative and qualitative approaches in gathering data to answer the research questions. Four instruments were utilized to collect the quantitative data: the Student Background Survey, the Pre-calculus Concept Assessment (PCA), the Science Motivation Questionnaire II (SMQ-II), and the Mindset Survey. To further explore the research questions beyond the numerical trends of quantitative data, qualitative data were collected in the form of interviews, observational notes, and written reflections. In addition, the researcher served as an instrument in the study.

Interventions Used

Many researchers have confirmed that non-cognitive factors and personal traits can promote learning and significantly influence success in academia (e.g., Dweck et al., 2011; Yeager et al., 2013). These psychological factors often involve students' individual beliefs and strategies that have developed over time, such as motivation, self-determination, self-efficacy, and mindset. As a result, there were two interventions used in this study: motivation and mindset. These two interventions occurred as part of regular class time and were led by a fellow doctoral student in mathematics education who was neither the researcher nor the instructor.

Mindset. The material for the mindset interventions included a TEDTalk (Briceno, 2012), during which the participants learned about the latest findings on malleability of the human brain. A rich class discussion occurred through the use of mindset intervention prompts (see Appendix K). Then the participants were asked to submit two writing exercises meant to reinforce the message just watched.

Motivation. All participants from the experimental group were provided with their pre-motivation report cards along with interventions in the form of two articles: one promoting self-efficacy (Margolis & McCabe, 2006) and the other self-determination (Chapman & Rupured, 2008). The experimental group had a class discussion led by the same doctoral student who implemented the mindset interventions. The participants considered the prompts sharing their perspectives on the two mentioned articles. After 30 minutes of class discussion, each participant in the experimental group wrote two reflections (see Appendices H and I).

Review of the Findings

The following sections present the results that focus on answering the research questions in the study. The first section includes the quantitative results pertaining to the first three research questions. The section contains the results from the PCA, the SMQ-II, and the Mindset Survey. In the second section, the qualitative results related to the fourth research question are addressed.

Quantitative Results

The analysis of the results from PCA and SMQ-II scores showed no statistically significant difference between the experimental and control groups at post-test after controlling for the pre-existing differences in the pre-tests scores. The results from the Mindset Survey were used in answering both parts of the third research question regarding mindset toward intelligence and mathematical ability. The findings from each mindset survey follows.

Mindset toward intelligence. In answering the first part of the third research question, there was a difference in the groups between the proportions of a growth mindset toward intelligence after the interventions. This difference was 3%, where the experimental group had the higher proportion of participants with a growth mindset toward intelligence. The results for answering the second part of this research question indicated that the proportion of participants in the experimental group with a growth mindset toward intelligence increased by 27% from their respective pre-proportion.

Mindset toward mathematical ability. The proportion of participants with a growth mindset in groups toward mathematical ability was different after the interventions. This difference was 10%, where the experimental group had the higher proportion of participants with a growth mindset toward mathematical ability. After the interventions, the results showed that the proportion of participants with a growth mindset toward mathematical ability had increased by 4% from pre to post in the experimental group.

Qualitative Results

The qualitative results were used to address the fourth research question: How do individuals of different mindset and/or motivation benefit, if at all, from the interventions? The case study participants benefited from the interventions in five ways. First, all four case study participants indicated that the motivation interventions had been beneficial for them, especially learning about the 10 strategies for time management. Second, after experiencing the mindset interventions, all case study participants had a growth mindset toward intelligence and mathematical ability. Third, the case study participants benefited from understanding the message of the TEDTalk video (Briceno, 2012), indicating how the perception toward a subject can significantly influence learning that subject. Fourth, the case study participants' writing samples and interviews also confirmed their understandings in the role that mindset played in learning and achievement. Fifth, all four case study participants indicated that after experiencing the mindset interventions, they had been more willing to make the effort in learning new things.

Discussion of Results

This study sought to examine the influence of two non-cognitive factors (i.e., motivation and mindset) in a reformed pre-calculus classroom. To answer the first three research questions, quantitative data and for the fourth research question qualitative data were collected. The discussion of results obtained from these two methods follows.

Quantitative Results

In this section the results to answer the first three research questions will be discussed. These research questions intended to find the effect of interventions on students' pre-calculus achievement, motivation toward learning mathematics, and mindset toward intelligence and mathematical ability. The discussion regarding each item follows.

Research question 1: Pre-calculus achievement. The first research question was: Do students in a reformed class who receive motivation and mindset interventions perform significantly better on a pre-calculus achievement test compared to students in a similar class who do not receive such interventions? This study found no significant difference between the post-PCA scores of the students in the experimental and the control groups. One possible explanation for this result was that in this study the participants in both the experimental and the control groups received the same reform-oriented instructions by the same instructor using the same textbook, lessons, and tests. Further, given the reform-oriented nature of the class, it is possible that by design the instruction met the diverse learning needs of students in both groups. According to researchers, the students in reform-oriented mathematics classrooms in colleges that focused on conceptual understanding of mathematical ideas and problem solving outperformed the students in traditional lecture-based classrooms that concentrated on routine algebraic manipulations (e.g., Erickson & Shore, 2003; Gordon, 2006; Hurley, Koehn, & Ganter, 1999; Lawson et al., 2002). Therefore, it was not surprising that, on the average, the performance of participants in terms of pre-calculus achievement in these two reformed classes were similar.

The second possible explanation for no statistical difference between groups on pre-calculus achievement may have been related to the fact that the motivation interventions (see Appendices H and I) were not exactly aimed at promoting students' motivation toward learning mathematics. The motivation interventions consisted of strategies that could have been used not only to promote mathematics learning but could also inspire the participants to use them to improve learning in general or in other aspects of their lives (Post-interventions Interview, 11/23/2015). The participants learned about the four different ways to acquire self-efficacy and 10 strategies to manage their time wisely, but they chose not to use them in promoting their motivation toward learning mathematics influencing pre-calculus achievement. One of the possible reasons for this decision may be the fact that possessing only self-efficacy and time management skills was not enough to energize the participants to use them toward learning mathematics. According to Siegle and McCoach (2007), for students even with a high self-efficacy toward learning mathematics, additional effort and persistence is required to achieve success.

The third possible explanation for the non-significant results regarding pre-calculus achievement was the high percentage of participants with a growth mindset in both groups compared to the reported quantity in the literature. Dweck (2008) indicated that about 40% of students hold a fixed mindset, believing that intelligence is a gift and cannot be improved. Further, she reported that about 40% of students believe intelligence is malleable and can be improved by hard work and perseverance. The remaining 20% of students are not consistent in their choice and are not categorized. However, in this study before the interventions, the percentages of participants with a growth mindset toward intelligence in the control group and the experimental group were 82% and 53%, respectively. The percentages of participants with a growth mindset regarding mathematical ability were even higher: 86% for both groups. The participants in both groups entered the reformed classes possessing a much higher percentage of the growth mindset than expected, ready to work hard, persevere, and achieve success in pre-calculus. The presence of the high proportion of the students having a growth mindset toward intelligence and mathematical ability in reformed classrooms may have resulted in similar pre-calculus achievement between the two groups.

Research question 2: Motivation toward learning mathematics. The second research question was: Do students in a reformed class who receive motivation and mindset interventions show significant improvement in motivation towards mathematics compared to students in a similar class who do not receive such interventions? The differences between scores of motivations toward learning mathematics in groups were not statistically significant after the interventions. During the interview before the interventions, all four case study participants indicated that their future careers were the primary reason for their motivation to learn mathematics (Pre-interventions Interview, 9/7/2015). Unfortunately, one of the case study participants, Daniel, was not motivated to learn mathematics since he thought in his future career as a biologist he would not be required to use higher-level mathematics such as pre-calculus and calculus. In considering the sources of motivation, the scores obtained from the five motivation components assessed in SMQ-II confirmed that the participants earned high scores in the two extrinsic motivations (i.e., career motivation and grade motivation). According to Ryan and Deci (2000), students who are extrinsically motivated regarding a task could perform it with bitterness, struggle, and lack of interest or with an approach of readiness that echoes an internal recognition of the significance or usefulness of a task. Therefore, one of the possible explanations for the result of no significant difference for motivation toward learning mathematics between groups is the fact that scores of intrinsic motivation (i.e., the innate pleasure of learning mathematics for its own sake) that results in superior learning and inspiration (Ryan & Deci, 2000) were much lower than the scores of extrinsic motivation (i.e., learning mathematics as rationale to gain a tangible end, such as career and grades).

Another possible explanation for the result of research question two was the fact that in the motivation interventions (see Appendices H and I) the discussion questions regarding self-efficacy were meant to link this attribute to the growth mindset that participants learned the previous week. Similar to the definition of having a growth mindset, self-efficacy includes confidence in one’s ability to effectively perform and complete a task (Muis, Ranellucci, Franco, & Crippen, 2013). So actually, this part of the motivation interventions stressed the message of mindset interventions. The second part of the motivation interventions (Time management: 10 strategies for better time management) promoted self-determination through utilizing time management tactics. Although these strategies were meant to help the participants manage their time wisely so they could have more time to study mathematics, all case study participants confirmed using them in other aspects of their lives (Post-interventions Interview, 11/23/2015). The third likely explanation of no significant difference for motivation toward learning mathematics between groups was because the interventions did not address the use of mathematics in various STEM fields. The importance of informing STEM majors of how mathematics is used in their fields is based on the fact that for majority of students their motivation to learn mathematics is their career path. All case study participants in this study confirmed that their future career was their motive to learn mathematics (Pre-interventions Interview, 9/7/2015).

Research question 3(a): Mindset toward intelligence. The third research question was: Is there a difference in the proportion of students in groups with either a growth or a fixed mindset depending on condition at post-test? Does the proportion of students in the experimental group change from a fixed vs. a growth mindset from pre- to post-interventions? The results at post-test showed that there was a 3% difference in the proportion of students with a growth mindset toward intelligence between groups, where the experimental group had the higher proportion. The importance of this result was based on the fact that before the interventions, the experimental group's proportion of participants with a growth mindset (53%) was 29% less than that of control group (82%). To answer the second part of research question three, the proportion of participants with a growth mindset increased by 27% from pre to post (i.e., from 53% to 80%) in the experimental group. The proportion of participants in the control group with a growth mindset who did not receive interventions, actually decreased by 5% from pre to post (i.e., from 82% to 77%).

One possible explanation for these results is that participants in the experimental group understood the message of having a growth mindset through the interventions. This message helped them realize that intelligence is malleable and can be changed by hard work and perseverance. Learning new materials as the course progressed, more students from the experimental group held the growth mindset toward intelligence and were prepared to encounter obstacles. Alternatively, the control group that started with more students with the growth mindset toward intelligence compared to the experimental group, ended up with fewer students with the growth mindset at post-test. Researchers have confirmed that the mindset intervention activities such as a class discussion, writing, and learning about the benefits of having a growth mindset could solidify students' confidence in their abilities to persevere through challenges of learning (e.g., Dweck, 2008; Silva & White, 2013).

Research question 3(b): mindset toward mathematical ability. The third research question was: Is there a difference in the proportion of students in groups with either a growth or a fixed mindset depending on condition at post-test? Does the proportion of students in the experimental group change from a fixed vs. a growth mindset from pre-to post-interventions? The results at post-test showed that there was a 10% difference in the proportion of students with a growth mindset toward mathematical ability between groups, where the experimental group had the higher proportion. The proportion of participants in the experimental group with a growth mindset increased by 4% from pre to post (i.e., from 86% to 90%), the same proportion decreased in control group by 6% (i.e., from 86% to 80%). It is worth mentioning that the participants in groups started the semester with having the same high proportion of growth mindset toward mathematical ability (86%) in reformed pre-calculus course.

The mindset toward mathematical ability is quite different from mindset toward intelligence. Students who have a growth mindset about intelligence could have a fixed mindset toward mathematical ability, believing that some individuals are talented in mathematics and some are not (Boaler, 2016; Willingham et al., 2016). The reason for this destructive belief is the convincing and often undesirable ideas about mathematics that students have. When comparing the higher proportion of participants with the growth mindset toward mathematical ability to mindset toward intelligence before the interventions, one possible explanation for these results is that both groups had learned a valuable lesson from their previous mathematics classes, realizing that with hard work, practice, and persistence in learning mathematics they can achieve success. As the course progressed, more students in the experimental group realized that they could change their mathematical ability if they persevere, making efforts to overcome the challenges and obstacles of learning mathematics. However, the proportion of participants with a growth mindset toward mathematical ability in the control group who did not understand the role of mindset in learning decreased by 6%. Not owning a true growth mindset, the participants' mindset change was possibly due to the lack of tenacity when they were confronted with the challenges of learning new materials during the pre-calculus course. Often many high-achieving students in mathematics classes see hard work and struggle as a sign of failure while achieving effortlessly as an indication of success (Boaler, 2016).

The mindset interventions helped decrease the number of participants with a fixed mindset toward mathematical ability to only one student in the experimental group at the post-test.

Qualitative Results

In this section, the qualitative results are presented to discuss the fourth research question: How do individuals of different mindset and/or motivation benefit, if at all, from the interventions? All case study participants, whether they started out as having a growth or a fixed mindset, perceived themselves as comprehending and possessing a growth mindset toward intelligence and mathematical ability after the interventions. The writing samples and interviews had reported changes toward creating a growth mindset in the case study participants with a fixed mindset (i.e., Adele and Crystal), and solidifying this mindset in participants who began with a growth mindset (i.e., Daniel and Marge). However, since the case study participants had completed the pre-calculus course in high school (McGowen, 2006), they likely did not encounter an enormous obstacle to overcome while learning the same material in college. Therefore, it is not clear if the interventions were effective enough for them to sincerely possess a growth mindset. Although, the mindset interventions were beneficial for the case study participants, the continuance of the impact of the interventions and its outcomes on academic achievement are not known. While all case study participants perceived benefits from the motivation interventions, they did not report a change in their motivation to learn mathematics.

Implications

The results from this study can inform both teachers and administrators in mathematics classes of similar settings at comparable colleges and universities. One of the implications of this study would be to include specific strategies for promoting students' motivation to learn mathematics. The motivation interventions used were not aimed at improving students' motivation toward learning mathematics specifically. Rather, they included general strategies to promote self-efficacy and self-determination, which did not lead to a significant difference in the motivation of students toward learning mathematics.

All case study participants indicated that their motivation to learn mathematics was their career path. Therefore, the second implication from this study would be to have motivation interventions directly address how mathematics is being used in various STEM fields. Some STEM students, including the ones majoring in biology, may think that their future careers do not require high-level mathematics. Interventions aimed at informing students about the use of mathematics in their fields would potentially motivate them to learn mathematics.

A theoretical implication from this study is based on the proportion of STEM majors with a growth mindset toward intelligence compared to the expected quantity identified in the literature. Since before the interventions the proportion of participants in both groups with a growth mindset toward intelligence was higher than expected, a theoretical implication would be that this proportion is likely higher in students who major in STEM fields, compared to that of the general population. Further, the results indicated a higher proportion of STEM students with a growth mindset toward mathematical ability than the proportion toward intelligence. This outcome could serve to inform the mathematics educators in classes with students majoring in STEM careers.

Future Research

The results of this study were promising, although not statistically significant. In the following paragraphs directions for future studies are presented.

A larger sample size would have been preferred in order to increase the statistical power of the study, since the statistical power of this study was limited by its small sample size. To obtain a higher level of confidence in the results, researchers should consider replicating this study with a much larger sample size.

Additionally, the mindset interventions in this study were conducted only one time during an academic semester. Researchers could study the effect of posting the growth mindset messages and prompts on students' webpage accounts throughout the semester. Moreover, it is not clear to what extent the influence of the growth mindset teaching lasts with the learners. A future study should track students through more advanced mathematics classes such as calculus courses to find out if they really had maintained a growth mindset.

The effect of mindset interventions was not examined across race and gender in this study. Researchers could study the influence of mindset interventions on reformed pre-calculus students majoring in STEM by race and gender. Past studies have shown that female and African-American students benefited the most from the mindset interventions (Dweck, 2008).

In this study, the proportion of students with a growth mindset toward intelligence was far higher than reported in literature. This result may mean that more students majoring in STEM have a growth mindset toward intelligence and mathematical ability compared to the general public or to non-STEM majors. A future study could examine this possible difference among college students majoring in STEM, non-STEM majors, and the general public if there is any. If the gap is large, similar to this study, then it perhaps means many students could have benefited from the mindset interventions before declining to major in STEM fields.

Chapter Summary

The capital and achievements of a nation are established on many factors. The education system plays a significant role in capital and achievements. A national priority in the U.S is to improve the quality and quantity of STEM graduates from college and universities. One of the approaches for increasing the number of graduates in STEM fields is to focus on promoting students' non-cognitive factors and personal traits such as motivation and mindset. This study highlighted the importance of understanding how students' mindset can influence the way they learn. Promoting the message of a growth mindset among college students majoring in STEM can teach them that success is attainable with hard work, practice, and perseverance. There has been rather little research on mindset on college students. Therefore, this study served as a contribution to the existing information regarding how mindset interventions can influence students in higher education as well as a motivation for more study on how mindset can improve academic achievements.

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APPENDICES

APPENDIX A - Student Background Survey

Name _______________

The purpose of this survey is to gather background information of students participating in this study. The information will be used to describe the group of students participating in the study. Individual data will not be shared.

Directions: Please read each question and respond accordingly.

1. What is your gender? (Circle one) Male Female I do not wish to respond.

2. In what year were you born? ______ Check here if you do not wish to respond.______

3. Hispanic/Latino origin (circle one) Yes No I do not wish to respond.

4. Please specify your race. ________ Check here if you do not wish to respond.______

5. What is your major? ___________ Check here if you do not wish to respond.______

6. Is this your first time taking Precalculus? (Circle one) Yes No I do not wish to respond.

   If no, which term best describes your previous Precalculus class? (Check one)

   ______ The teacher lectured. Students were not involved during class.

   ______ The teacher and students were actively involved during class.

   ______ I do not wish to respond.

7. What was your high school grade point average? ____ Check here if you do not wish to respond.______

8. What was your ACT score in mathematics? _____Check here if you do not wish to respond______

9. I prefer online learning to face-to-face instruction. Yes No I do not wish to respond.

10. In mathematics class, I prefer to work in groups as opposed to working individually.

    (Circle one) Yes No I do not wish to respond.

APPENDIX B - Precalculus Concept Assessment (PCA)

1) Given the function f, defined by f(x) = 3x2+ 2x - 4, find f(x + a)

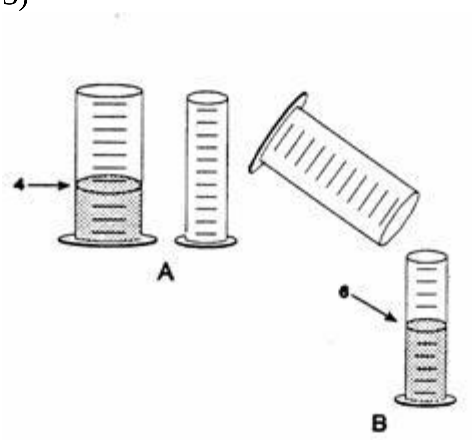
a) f(x + a) = 3x2 + 3a2 + 2x + 2a - 4
b) f(x + a) = 3x2 + 6xa + 3a2 + 2x - 4
c) f(x + a) = 3 (x + a)2 + 2(x + a) - 4
d) f(x + a) = 3 (x + a)2 + 2x - 4
e) f(x + a) = 3x2 + 2x - 4 + a

2) Use the graph of *f* to solve f(x) = -3 for x

[redacted]

a) (-3,-2)
b) -4
c) (-4,-3)
d) -2
e) -3

3)



Above are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B).

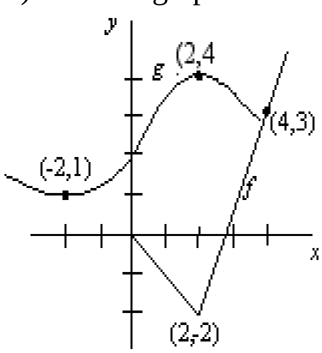
Both cylinders are emptied, and water is poured into the narrow cylinder up to the 11th mark. How high would this water rise if it were poured into the empty wide cylinder?

a) To the 71/2 mark
b) To the 9th mark
c) To the 8th mark
d) To the 71/3 mark
e) To the 11th mark

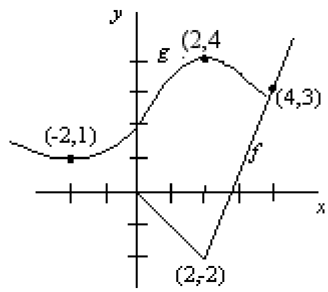
4) Which one of the following formulas defines the area, *A*, of a square in terms of its perimeter, *p*?

a) $A = \frac{p^2}{16}$
b) $A = s^2$
c) $A = \frac{p^2}{4}$
d) $A = 16s^2$
e) $P = \frac{4}{\sqrt{A}}$

5) Use the graphs of f and g to evaluate g(f(2))



a) -2
b) 1
c) 3
d) 4
e) Not Defined



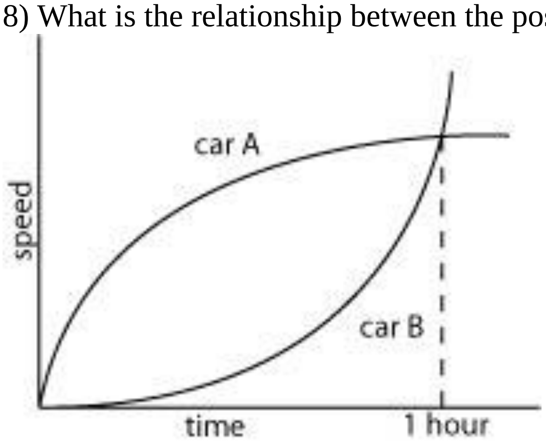
6) Evaluate *f*(2) - *g*(0).

a) -4
b) -2
c) 0
d) 2
e) 4

7) The model that describes the number of bacteria in a culture after t days has just been updated from $P(t) = 7(2)^t$ to $P(t) = 7(3)^t$. What implications can you draw from this information?

a) The final number of bacteria is 3 times as much of the initial value instead of 2 times as much.
b) The initial number of bacteria is 3 instead of 2.
c) The number of bacteria triples every day instead of doubling every day.
d) The growth rate of the bacteria in the culture is 30% per day instead of 20% per day.
e) None of the above.

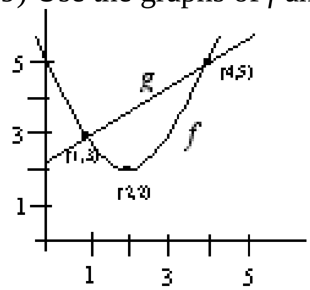
8) What is the relationship between the position of car A and car B at t = 1 hr.?



a) Car A and car B are colliding.
b) Car A is ahead of car B.
c) Car B is ahead of car A.
d) Car B is passing car A.

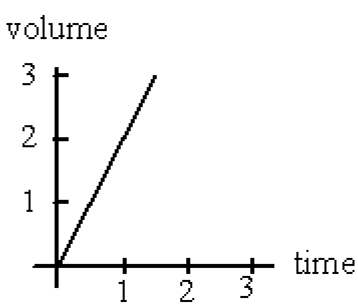
e) Cars are at same position.

9) Use the graphs of *f* and *g* to solve *g(x)* > *f(x)*.



a) 2 < x < 5
b) 1 < y < 4
c) x < 4
d) 2 < y < 5
e) 1 < x < 4

10) A hose is used to fill an empty wading pool. The graph shows volume (in gallons) in the pool as a function of time (in minutes). Which of the following defines a formula for computing the time, t, as a function of the volume, v?



a) $v(t) = \frac{t}{2}$
b) $t(v) = 2v$
c) $t(v) = \frac{v}{2}$
d) $v(t) = 2t$
e) None of the above

11) The distance, s (in feet), traveled by a car moving in a straight line is given by the function, $s(t) = t^2 + t$, where t is measured in seconds. Find the average velocity for the time period from t = 1 to t = 4.

a) 5 ft. /sec
b) 6 ft. /sec
c) 9 ft. /sec
d) 10 ft. /sec
e) 11 ft. /sec

12)

x	*f(x)*	*g(x)*
-2	0	5
-1	6	3
0	4	2
1	-1	1
2	3	-1
3	-2	0

Given the table above, determine *f(g(3))*

a) 4 b) -1
c) 0 d) 1
e) 5

13)

x	*f(x)*	*g(x)*
-2	0	5
-1	6	3
0	4	2
1	-1	1
2	3	-1
3	-2	0

Given the table above, determine $g^{-1}(-1)$

a) -1 b) 0
c) 1 d) 2
e) 3

4) Given that f is defined by $f(t) = 100^t$, which of the following is a formula for f^{-1} ?

a) $f^{-1}(t) = \frac{1}{100^t}$

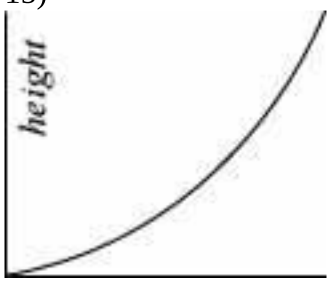
b) $f^{-1}(t) = \frac{t}{\ln 100}$

c) $f^{-1}(t) = \frac{t}{100^t}$

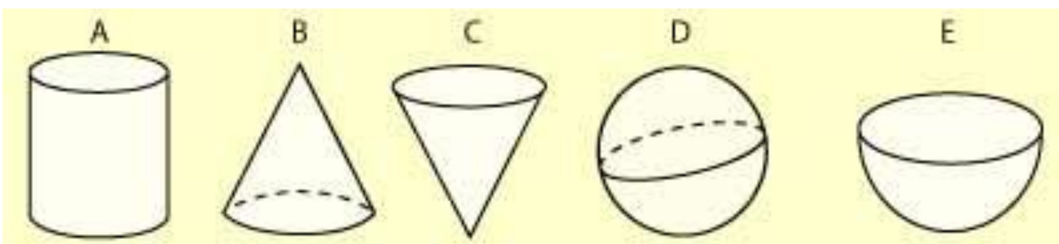
d) $f^{-1}(t) = \frac{\ln t}{\ln 100}$

e) $f^{-1}(t) = \frac{\ln t}{100}$

15)



The above graph represents the height of water as a function of volume as water is poured into a container. Which container is represented by this graph?



16) Given the function $h(x) = 3x - 1$ and $g(x) = x^2$, evaluate $g\big(h(2)\big)$.

a) 10
b) 11
c) 20
d) 25
e) 36

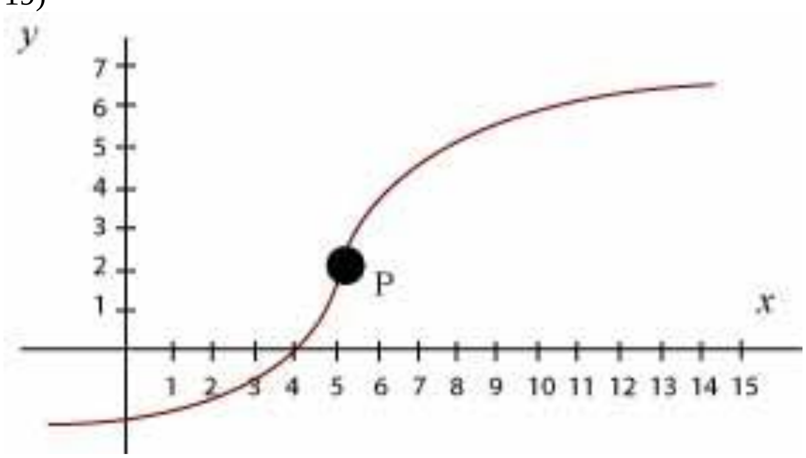
17) A ball is thrown into a lake, creating a circular ripple that travels outward at a speed of 5 cm per second. Express the area, A, of the circle in terms of the number of seconds, s, that have passed since the ball hits the lake.

a) $A = 25\pi s$
b) $A = \pi r^2$
c) $A = 25\pi s^2$
d) $A = 5\pi s^2$
e) None of the above

18) The wildlife game commission poured 5 cans of fish (each can contained approximately 100 fish) into a farmer's lake. The function N defined by $N(t) = \frac{600t+5}{0.5t+1}$, represents the approximate number of fish in the lake as function of time (in years). Which one of the following best describes how the number of fish in the lake changes over time?

a) The number of fish gets larger each year, but does not exceed 500.
b) The number of fish gets larger each year, but does not exceed 1200.
c) The number of fish gets smaller every year, but does not get smaller than 500.
d) The number of fish gets larger each year, but does not exceed 600.
e) The number of fish gets smaller every year but does not get smaller then 1200.

19)



Using the graph below, explain the behavior of function f on the interval from x = 5 to x = 12.

a) Increasing at an increasing rate.
b) Increasing at a decreasing rate.
c) Increasing at a constant rate.
d) Decreasing at a decreasing rate.
e) Decreasing at an increasing rate.

20) If S(m) represents the salary (per month) of an employee after m months on the job, what would the function R(m) =S(m + 12) represent?

a) The salary of an employee after m + 12 months on the job.
b) The salary of an employee after 12 months on the job.
c) $12 more than the salary of someone who has worked for m months.
d) An employee who has worked for m + 12 months.
e) Not enough information.

21) What is the domain of the following function? $f(x) = \frac{\sqrt{x+2}}{x-1}$

a) $(1, +\infty)$ b) $\{x|x \neq -1\}$
c) $(-2, 1)U(1, +\infty)$ d) $(-2, +\infty)$
e) All real numbers

22) A baseball card increases in value according to the function, $b(t) = \frac{5}{2}t + 100$, where b gives the value of the card in dollars and t is the time (in years) since the card was purchased. Which of the following describe what $\frac{5}{2}$ conveys about the situation?

I. The card's value increases by $5 every two years.
II. Every year the card's value is 2.5 times greater than the previous year.
III. The card's value increases by $\frac{5}{2}$ dollars every year.

a) I only
b) II only
c) III only
d) I and III only
e) I, II and III

23) Which of the following best describes the effect of f^{-1} , given f is a one-to-one function and $f(c) = d$?

a) f^{-1} inverts , so $f^{-1}(d) = \frac{1}{f(d)}$
b) f^{-1} inverts the input to f, so, $f^{-1}(d) = \frac{1}{d}$
c) f^{-1} inverts the output to f, so, $f^{-1}(d) = \frac{1}{c}$
d) f^{-1} inverts f , so $f^{-1}\left(f(d)\right) = d$
e) A and C

24) A function *f* is defined by the following graph. Which of the following describes the behavior of *f* ?

I. As the value of x approaches 0, the value of f increases.
II. As the value of x increases, the value of f approaches 0.
III. As the value of x approaches 0, the value of f approaches 0.

a) I only
b) II only
c) III only
d) I and II
e) II and III

25) Which of the following best describes the behavior of the function *f* defined by?

$$f(x) = \frac{x^2}{x-2}$$

I. As the value of x gets very large, the value of f approaches 2.
II. As the value of x gets very large, the value of f increases.
III. As the value of x approaches 2, the value of f approaches 0.

a) I only
b) II only
c) III only
d) I and II
e) II and III

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The instrument was retrieved from
https://mathed.asu.edu/instruments/pca/vH/index.shtml

APPENDIX C - Science Motivation Questionnaire II (SMQ-II)

Name _____________ Major_____________ Circle: Male/Female

In order to better understand what you think and how you feel about your mathematics courses please respond to each of the following statements from the perspective of **"When I am in a mathematics course . . ."**

Items	Never	Rarely	Sometimes	Often	Always
1. The mathematics I learn is relevant to my life					
2. I like to do better than other students on mathematics tests.					
3. Learning mathematics is interesting.					
4. Getting a good mathematics grade is important to me.					
5. I put enough effort into learning mathematics.					
6. I use strategies to learn mathematics well.					
7. Learning mathematics will help me get a good job.					
8. It is important that I get an "A" in mathematics.					
9. I am confident I will do well on mathematics tests.					
10. Knowing mathematics will give me a career advantage.					
11. I spend a lot of time learning mathematics.					
12. Learning mathematics makes my life more meaningful.					

13. Understanding mathematics will benefit me in my career.					
14. I am confident I will do well on mathematics labs and projects.					
15. I believe I can master mathematics knowledge and skills.					
16. I prepare well for mathematics tests and labs.					
17. I am curious about discoveries in mathematics.					
18. I believe I can earn a grade of "A" in mathematics.					
19. I enjoy learning mathematics.					
20. I think about the grade I will get in mathematics.					
21. I am sure I can understand mathematics.					
22. I study hard to learn mathematics.					
23. My career will involve mathematics.					
24. Scoring high on mathematics tests and labs matters to me.					
25. I will use mathematics problem-solving skills in my career.					

Glynn,S.M.(2011). Science Motivation Questionnaire II . Retrieved from
http://coe.uga.edu/assets/docs/outreach/smqii/SMQII-Glynn.pdf

APPENDIX D - Mindset Survey

Name Major Circle: Male/Female

For each of the following statements, rate how strongly you agree or disagree with the statement. There is no right or wrong answers.	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
You have a certain amount of intelligence and you really can't do much to change it.	1	2	3	4	5	6
Your intelligence is something about you that you can't change very much.	1	2	3	4	5	6
You can learn new things, but you can't really change your basic intelligence.	1	2	3	4	5	6
A person has a certain amount of mathematical ability and they really can't do much to change it.	1	2	3	4	5	6
A person's mathematical ability is something about them that they can't change very much.	1	2	3	4	5	6
A person can learn new things about mathematics, but they can't really change their basic mathematical ability.	1	2	3	4	5	6

Source:

Dweck, C. S., Chiu, C., & Hong, Y. (1995). Implicit theories and their role in judgments and reactions: A world from two perspectives. *Psychological Inquiry*.*6*(4), 267-285.
Retreived from http://www3.ntu.edu.sg/home/YYHong/papers/journal/Implicit%20theories%20and%20their%20role%20in%20judgements%20and%20reactions.pdf

APPENDIX E - Observational Notes (in class before and after the interventions)

Instructor________________________ Lesson Title______________________________

The observational notes will be focused on capturing **what case study participants are saying during the class time**. The focus will be on the language that case study participants use to communicate with the instructor and their classmates. The researcher will locate the four case study participants in the class first and then starts listening to their conversation and takes notes.

	What Are the Case Study Participants (CSP) Saying?				
Components of class	*CSP #1*	*CSP #2*	*CSP #3*	*CSP #4*	*Time*
Warm Up					
Lesson of the Day					
Group work					
Individual work time					
Wrap-up					
Total Number of Growth Mindset Comments and Examples					
Total Number of Fixed Mindset Comments and Examples					

After the observation is over, the notes from the case study participants will be reviewed by the researcher. The number of times that growth mindset language or fixed mindset language has been used by the four case study participants with examples will be recorded. In the following, some examples of growth/fixed mindset language are presented.

Examples of students’ language with the fixed mindset:

- I’m stuck; I have never been good in math!
- This is hard; I can’t solve this!
- I am a slow learner!

Examples of students’ language with the growth mindset:

- Math is challenging and I like challenges!
- I can solve it if I try hard enough!
- I may not be as fast as my classmates but I will improve with practice!

APPENDIX F - One-to-One Interview (before the interventions)

Name: ____________

1) How do you compare traditional mathematics classrooms with reform-oriented ones? What are the advantages/ disadvantages of each?

2) How important of a role do you think mathematics plays in our lives?

3) What have been the most interesting topics so far in Precalculus for you?

4) What motivates you to learn mathematics and why?

5) What strategies do you use to improve your grade if you were to fail your first exam in this class?

APPENDIX G - One-to-One Interview (after the post-tests)

Name: ____________

Let the participant know that the questions in this interview are related to their total experience about interventions received during Precalculus class this semester.

1) Have the interventions enhanced your motivation and mindset toward mathematics? If so, in what way? If not, why not?

2) How do you think this experience can influence other aspects of your life, if at all?

3) What was the most interesting part of the interventions, if any? Explain why it was so interesting to you.

4) How has your attitude toward learning a new skill or craft changed, if at all? If so, why? If not, why not?

5) What was the most important lesson that you learned from the interventions? How can it influence your future?

APPENDIX H - Motivation Intervention (a self-efficacy article)

As a motivation intervention, the participants were asked to review the following article about self-efficacy.

Margolis, H. & McCabe P. (2006). Improving self-efficacy and motivation: what to do, what to say. *Intervention in School and Clinic*, *41* (4), 218–227.

One week later, a doctoral student in mathematics education led a class discussion (duration 15 minutes) on this article. She asked the participants to discuss each question (see below) in groups and then called on several students to express their groups' opinions. The discussion prompts and the timeline follow.

Warm-up: Talking about the definition of self-efficacy: Self-efficacy is a belief, a judgment that you can succeed in a particular task. So, an individual may have a high self-efficacy in cooking but not in painting.

1. What is the relation between having self-efficacy and a growth mindset?
2. How can self-efficacy be improved?
3. Think about this question and reply in self-efficacy response part: In your own words, explain how you can improve your self-efficacy in learning mathematics. From the four ways discussed to improve self-efficacy, which one has been the most effective for you?

Timeline for Implementing Motivation Interventions on Monday 9/21/2015

Performed by a PhD student in Mathematics Education

Activity	Duration	Time
Warm-up	1 minutes	11:31 a.m.
Discussing the 1st question	3 minutes	11:34 a.m.
Discussing the 2nd question	6 minutes	11:40 a.m.
Reflecting on the 3rd question	5 minutes	11:45 a.m.

APPENDIX I - Motivation Intervention (a self-determination article)

As an intervention for motivation toward mathematics, the participants were asked to review the following article about time management.

Chapman, S. W., & Rupured, M. (2008). *Time management: 10 strategies for better time management* (Publication # HACE-E-71). The University of Georgia: Georgia.

A class discussion (duration 15 minutes) led by a doctoral student in mathematics education regarding this article was conducted one week later. She asked the participants to discuss each question in groups and then called on several students to express their groups' opinions. The discussion prompts and the timeline follow.

Warm-up: Talking about the definition of self-determination: Self-determination is the belief that you have control over what to think or do without outside influence. To obtain high self-determination, excellent time management is required. Why do you think time management is important? Every day you are gifted with 86,400 seconds of life which cannot be re-lived. Keep in mind: failing to plan is planning to fail. The article suggests 10 useful strategies for better time management.

1. How many of you know exactly what you will be doing in the next 5 hours? What about next week, next month? The first strategy in the article was: How do you spend your time?

2. Well, the third strategy is to use a planning tool such as electronic planners or calendars to improve your productivity. You need two planners. One can be a long-time planner which will include all your exams, due dates, appointments, important dates, and final exams. The second planner can be a weekly schedule to write down your class

times, study, work, commute, social and family times. Ameneh will be handing out both to you now. Let's start working on weekly schedule now; you may work on the calendar for long-time planning at home. Remember you need 2 hours of studying time per credit hours per week (e.g., your class is 4 credit hours so it needs 8 hours of studying time per week). The best time to study any subject is after the class when the material is fresh in your mind. Make adjustments as you see fit to improve your productivity.

Think about this question and reply in time management response part: In your own words, explain how you can improve your time management. From the ten strategies suggested in the article to improve time management, which one has been the most effective for you?

Timeline for Implementing Motivation Interventions on Monday 9/21/2015

Performed by a PhD student in Mathematics Education

Activity	Duration	Time
Warm-up	2 minutes	11:47 a.m.
Discussing the 1st question	1 minutes	11:48 a.m.
Discussing the 2nd question	7 minutes	11:55 a.m.
Reflecting on the 3rd question	5 minutes	12:00 noon

APPENDIX J - Mindset Intervention (a letter to a hopeless student)

Vanessa is an intelligent young woman eager to start her college life and pursue her dream career in nursing. On the first day of classes, she was nervous and a little intimidated. But with her excellent GPA in high school, she thought to herself, “I’m smart. I’ll be fine.” One month later, despite her high math grades in high school, she failed the first exam in statistics, a course that plays an important role in her admission to the nursing program. She has started questioning everything: “Am I supposed to be here? Am I good enough?”

The participants in the experimental group watched: The Power of Belief” TEDTalk video (Briceno, 2012) and heard the class discussion on having a growth mindset (see Appendix K). Then the participants were asked to use what they have learned today and give her advice (duration 12 minutes).

Khanacademy & PERTS (n.d.). *Growth mindset lesson plan*. Retrieved from https://www.mindsetkit.org/static/files/YCLA_LessonPlan_v10.pdf

APPENDIX K - Mindset Intervention ("The Power of Belief" video)

Participants were asked to discuss (duration 55 minutes) the important points of "The Power of Belief" TEDTalk video (Briceno, 2012). The following prompts were used to help them discuss the significant aspects of this video. The discussion prompts and the timeline follow.

Initial writing: Think about this question and reply in initial writing response part: Is your intelligence fixed (you can't change it) or can it be improved?

1. Briefly discuss Josh's story and the quote • "The moment we believe that success is determined by an ingrained level of ability, we will be brittle in the face of adversity." - Josh Waitzkin

2. Mindset
   a) What is a growth mindset?
   b) What is a fixed mindset?

3. Discussion about the differences in Growth and Fixed Mindsets:
   a) What do people with fixed mindset focus the most on?
   b) How do people with a growth and fixed mindset view efforts?
   c) How do people with a growth and fixed mindset view obstacles?

Think about this question and reply in final writing response part: In your own words, describe a growth and fixed mindset and share your personal experience related to the effect of mindset in your life.

Briceno, E. (2012). *The Power of belief -- mindset and success.* Retrieved from https://www.youtube.com/watch?v=pN34FNbOKXc

Khanacademy & PERTS (n.d.). *Growth mindset lesson plan*. Retrieved from https://www.mindsetkit.org/static/files/YCLA_LessonPlan_v10.pdf

Timeline for Implementing Mindset Interventions on Monday 9/14/2015

Performed by a PhD student in Mathematics Education

Activity	Duration	Time
Initial Writing Response	5 minutes	11:35 a.m.
Watch the video (stop at 1:57)	3 minutes	11:38 a.m.
Put the 1st question (a quote) on Elmo and discuss it in groups	5 minutes	11:43 a.m.
Watch the video (stop at 4:20)	3 minutes	11:46 a.m.
Put the 2nd question (both parts) on Elmo and discuss it in groups	8 minutes	11:54 a.m.
Watch the video (stop at 5:36)	2 minutes	11:56 a.m.
Discuss the first part of the third question (Focus)	3 minutes	11:59 a.m.
Discuss the second part of the third question (Efforts)	3 minutes	12:02 p.m.
Discuss the third part of the third question (Obstacles)	3 minutes	12:05 p.m.
Watch the rest of the video	5 minutes	12:10 p.m.
Instruction to write the final writing response and reply to the prompt in back of the page (see Appendix J)	12 minutes	12:22 p.m.
Handing out the motivation report cards with pre-SMQ scores, and articles for motivation intervention to be discussed next week.	3 minutes	12:25 p.m.

APPENDIX L - Written Reflection (after the interventions)

Name: ____________

The following questions focus on your recent experience with motivation/mindset intervention toward learning mathematics. Please answer each question, providing as much detail as possible. If you need additional space, please use the back of the form or ask for an extra sheet of paper.

1) How has your motivation toward learning mathematics changed, if any?

2) How have the motivation interventions promoted your interest in learning mathematics?

3) What did you learn during the mindset interventions that surprised you?

4) How does an individual's mindset about intelligence impact his/her learning?

5) How has your experience during interventions changed your perception toward learning in general?

APPENDIX M - IRB

INSTITUTIONAL REVIEW BOARD
Office of Research
Compliance, 010A
Sam Ingram Building,
2269 Middle
Tennessee Blvd
Murfreesboro, TN
37129

EXPEDITED PROTOCOL APPROVAL NOTICE

8/10/2015
Investigator(s): Ameneh M. Kassaee (PI) and Angela Barlow Investigator(s)
Email: amk4e@mtmail.mtsu.edu; angela.barlow@mtsu.edu
Department: Mathematics & Science Education
Protocol Title: "Examining the role of motivation and mindset in the performance of college students majoring in STEM"
Protocol ID: 16-005

Dear nvestigator(s),

The MTSU Institutional Review Board (IRB), or its' representative, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an **EXPEDITED** review under 45 CFR 46.110 and 21 CFR 56.110 within the category *(7) Research on individual or group characteristics or behavior* This approval is valid for one year from the date of this letter **for 60 (SIXTY) participants** and it expires on **8/10/2016**.

Any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918 within 48 hours of the incident. Any change(s) to this protocol must be approved by the IRB. The MTSU HRP defines a "researcher" as someone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to complete the required training. New researchers can be amended to this protocol by submitting an Addendum request researchers to the Office of Compliance before they begin to work on the project.

Completion of this protocol MUST be notified to the Office of Compliance. A "completed research" refers to a protocol in which no further data collection or analysis is carried out. This protocol can be continued up to THREE years by submitting annual Progress Reports prior to expiration. Failure to request for continuation will automatically result in cancellation of this protocol and you will not be able to collect or use any new data.

All research materials must be retained by the PI or the faculty advisor (if the PI is a student) for at least three (3) years after study completion. Subsequently, the researcher may destroy the data in a manner that maintains confidentiality and anonymity. IRB reserves the right to modify, change or cancel the terms of this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board

Middle Tennessee State University

IRBN001 Version 1.0 Revision Date 05.11.2015